# THE POCKET BOOK OF REFRIGERATION AND ICE-MAKING

EDITED BY

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# PREFACE.

WHEN the first edition of this Pocket Book was published in 1902, refrigeration was already a flourishing industry, and the time seemed to be a proper one for the compilation in a handy form of such formulæ, data, tables, general memoranda, and useful information, as might be of service for constant reference to engineers and others interested in refrigeration, cold storage, and ice-making. That the work has proved of some service to those interested in the above subjects is evidenced by its having now reached a sixth edition.

The present edition has been carefully revised and several errors have been corrected. Some sixteen pages of new matter have been added as well as several fresh illustrations, and the index has been entirely remade and considerably extended.

The subjects are dealt with in six sections, and are classified under the following main heads: Section I. Refrigeration in General; Section II. Cold Storage; Section III. Ice-Making and Storing Ice; Section IV. Insulation; Section V. Testing and Management of Refrigerating Machinery; and

Section VI. General Memoranda, Tables, etc. The matters included under the above headings are far too numerous to admit of any further mention of them being made here, some idea of the ground covered, however, can be obtained by glancing through the table of principal contents, and it is trusted that the sixth edition will meet the requirements of those needing such a work in a still more satisfactory manner than the previous ones.

In conclusion, the editor desires to intimate that any criticisms, and practical suggestions for improvement, from any of the readers of the book, will be gladly welcomed. Any such communications—which should be addressed to the publishers —will receive every attention, with a view to the improvement of future editions.

THE EDITOR.

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# THE POCKET-BOOK OF REFRIGERATION AND ICE-MAKING.

## SECTION I.

## REFRIGERATION IN GENERAL.

### THE MECHANICAL THEORY OF HEAT.

HEAT pervades every substance known. Lord Armstrong said, "According to the new theory, heat is an internal motion of molecules, capable of being communicated from the molecules of one body to those of another; the result of this imparted motion being either an increase of temperature or the performance of work." The result of Joule's experiments was to demonstrate that under all circumstances the quantity of heat generated by the same amount of force is fixed and invariable. Professor Clerk Maxwell was of the opinion that heat, considered with respect to its power of warming things and changing their state, is a quantity strictly capable of measurement, and not subject to any variation of quality or kind.

The deductions to be arrived at on accepting this theory are, that if heat is a motion it must be an eternal one; the generation of heat in any substance must be additional to the heat that has been already generated in it or transferred thereto; heat can be lost or done away with to a degree only, as it is always of uniform quality, and it follows therefore that its annihilation must in every case be a definite part of the entire amount, and cannot be a reduction in quality.

The rational conclusion to be come to from the above is that the reduction of temperature or cooling of any substance is simply the withdrawal or annihilation of a greater or lesser part of its own heat.

Refrigeration may be defined as the art of reducing the temperature of any body, or of maintaining the said temperature below that of the atmosphere.

## Refrigerating Apparatus.

Widely, refrigerating apparatus may be classed under two main heads, viz. chemical and mechanical.

In the first, or apparatus working on the chemical system, the more or less rapid dissolution of a solid is utilised to abstract heat, and it is generally designated the liquefaction process.

The second, or mechanical process, comprises apparatus operating on four different systems, viz.: cold-air machines, in which the air is first compressed, then cooled, and afterwards permitted to expand whilst doing work, that is to say, practically, by first applying heat to ultimately produce cold; vacuum machines, wherein the evaporation of a portion of the liquid to be cooled, assisted by the action of an air-pump, and of sulphuric acid, effects the abstraction of heat; absorption machines, in which the abstraction of heat is effected by the evaporation of a separate refrigerating agent of a more or less volatile nature, under the direct action of heat, which agent again enters into solution with a liquid; and lastly, compression machines, wherein the abstraction of heat is effected by the evaporation of a separate refrigerating agent of a more or less volatile nature, which agent is subsequently restored to its original physical condition by mechanical compression and cooling.

## The Chemical or Liquefaction Process.

During the change of the physical condition of a substance, for instance, whilst it is passing from a solid to a liquid form, the cohesive force is overcome by energy in the

form of heat, and this may be brought about without change in sensible temperature, provided the heat be absorbed as fast as it is supplied from the exterior, as in the case of melting ice, the temperature of which remains constant at 32° Fahr., any increase or decrease in the heat supplied simply hastening or retarding the rate of melting, but in no way affecting the temperature. Mixtures composed of some salts with water or acids, and of certain salts with ice, however, forming liquids having freezing points lower than the original temperatures of the mixtures, act in a different manner, the tendency to pass into the liquid form being in this case so strong that a more rapid absorption of heat takes place than is capable of being supplied from without, and consequently a consumption takes place of the store of heat of the melting substances themselves. The natural result of this action is that the temperature of the latter falls, until such time as the rate of melting and the rate at which heat is supplied from the exterior become equalised. The degree to which the temperature can be lowered depends to a certain extent on the state of hydration of the salt and the percentage of it present in the mixture. The salts used in ordinary freezing mixtures are generally those of certain alkalies which almost exclusively possess the necessary degree of solubility at low temperatures, and the following table gives the mixtures usually employed :—

TABLE OF PRINCIPAL FREEZING MIXTURES.

| COMPOSITION OF FREEZING MIXTURES. | Reduction of temperature in degrees Fahr. From | To | Amount of fall in degrees Fahr. |
|---|---|---|---|
| Snow or pounded ice 2 parts; muriate of soda 1 part .. .. .. .. .. .. | | − 5 | |
| Snow 5; muriate of sodium 2; muriate of ammonia 1 .. .. .. .. .. | | −12 | |
| Snow 24; muriate of sodium 10; muriate of ammonia 5; nitrate of potash 5 .. .. | | −18 | |
| Snow 12; muriate of sodium 5; nitrate of ammonia 5 .. .. .. .. .. | | −25 | |
| Snow 4; muriate of lime 5 .. .. .. | +32 | −40 | 72 |
| Snow 1; chloride of sodium or common salt 1 .. | +32 | 0 | 32 |
| Snow 2; muriate of lime crystallized 3 .. .. | +32 | −50 | 82 |
| Snow 3; dilute sulphuric acid 2 .. .. .. | +32 | −23 | 55 |
| Snow 3; hydrochloric acid 5 .. .. .. | +32 | −27 | 59 |
| Snow 7; dilute nitric acid 4 .. .. .. | +32 | −30 | 62 |
| Snow 8; chloride of calcium 5 .. .. .. | +32 | −40 | 72 |
| Snow 2; chloride of calcium crystallized 3 .. | +32 | −50 | 82 |
| Snow 3; potassium 4 .. .. .. .. | +32 | −51 | 83 |
| Snow 2; chloride of sodium 1 .. .. .. | | − 5 | |
| Snow 5; chloride of sodium 2; chloride of ammonia 1 .. .. .. .. .. | | −12 | |
| Snow 14; chloride of sodium 10; chloride of ammonia 5; nitrate of potassium 5 .. .. | | −18 | |
| Snow 12; chloride of sodium 5; nitrate of ammonia 5 .. .. .. .. .. .. | | −25 | |
| Snow 2; dilute sulphuric acid 1; dilute nitric acid 1 .. .. .. .. .. .. | −10 | −56 | 46 |
| Snow 12; common salt 5; nitrate of ammonia 5 | −18 | −25 | 7 |
| Snow 1; muriate of lime 3 .. .. .. | −40 | −73 | 33 |
| Snow 8; dilute sulphuric acid 10 .. .. .. | −68 | −91 | 23 |
| Chloride of ammonia 5; nitrate of potassium 5; water 16 .. .. .. .. .. .. | +50 | + 4 | 46 |
| Nitrate of ammonia 1; water 1 .. .. .. | +50 | + 4 | 46 |
| Chloride of ammonia 5; nitrate of potassium 5; sulphate of sodium 8; water 16 .. .. | +50 | + 4 | 46 |
| Sulphate of sodium 5; dilute sulphuric acid 4 .. | +50 | + 3 | 47 |
| Sulphate of sodium 8, hydrochloric acid 9 .. | +50 | − 0 | 50 |
| Nitrate of sodium 3; dilute nitric acid 2 .. | +50 | − 3 | 53 |
| Nitrate of ammonia 1; carbonate of sodium 1; water 1 .. .. .. .. .. .. | +50 | − 7 | 57 |
| Sulphate of sodium 6; chloride of ammonia 4; nitrate of potassium 2; dilute nitric acid 4 .. | +50 | −10 | 60 |
| Phosphate of sodium 9; dilute nitric acid 4 .. | +50 | −12 | 62 |
| Sulphate of sodium 6; nitrate of ammonia 5; dilute nitric acid 4 .. .. .. .. | +50 | −14 | 64 |

TABLE OF PRINCIPAL FREEZING MIXTURES—*Continued.*

| COMPOSITION OF FREEZING MIXTURES. (Materials previously cooled.) | Reduction of temperature in degrees Fahr. From | To | Amount of fall in degrees Fahr. |
|---|---|---|---|
| Phosphate of sodium 5; nitrate of ammonia 3; dilute nitric acid 4 .. .. .. .. | 0 | −34 | 34 |
| Phosphate of sodium 3; nitrate of ammonia 2; dilute mixed acid 4 .. .. .. .. | −34 | −50 | 16 |
| Snow 3; muriate of lime 4 .. .. .. | +20 | −48 | 68 |
| Snow 1; muriate of lime crystallized 2 .. .. | 0 | −66 | 66 |
| Snow 2; muriate of lime 3 .. .. .. | −15 | −68 | 53 |
| Snow 8; dilute sulphuric acid 3; dilute nitric acid 3 .. .. .. .. .. .. | −10 | −56 | 46 |
| Snow 3; dilute nitric acid 2 .. .. .. | 0 | −46 | 46 |
| Snow 1; dilute sulphuric acid 1 .. .. .. | −20 | −60 | 40 |
| Snow 2; muriate of lime crystallized 3 .. .. | −40 | −73 | 33 |
| Snow 8; dilute sulphuric acid 10 .. .. .. | −68 | −91 | 23 |

## COLD-AIR MACHINES.

This class of machine is based upon one of the simplest principles of physics, that is to say, that the compression of air or other gas generates heat, and the subsequent expansion of this air or gas, cold. Mechanical work and heat being respectively convertible, it naturally follows that if air or other gas be caused to perform certain work on a piston during expansion, the performance of this work will cause its store of caloric to become exhausted to a degree equal to the thermal equivalent of the work done, the air or other gas after expansion being at a lower temperature than that at which it was before expansion; that is, of course, provided always that no heat be supplied from any source to restore that so lost.

Cold-air machines all operate on the same general principle (see diagram, Fig. 1). The air is first compressed in a compressor, and the heat which is generated by this compression is removed by means of water, the cold air produced by expansion being employed for refrigeration. But there have been several notable

improvements during the past few years, practically removing most of the old defects, which make them compare favourably, with machines using more or less volatile agents, Cole's "Arctic" Machine being one that embodies important improvements.

The cycle of operations may be a perfect or closed one when the same air is in constant circulation, or where it is desirable to have pure air in the storage chambers, the air is rejected after once passing through the cycle, and fresh air is admitted at each stroke of the compressor.

Air machines, working at a comparatively low pressure, necessitate the compression and expansion cylinders being of a larger size than in compression machines using higher

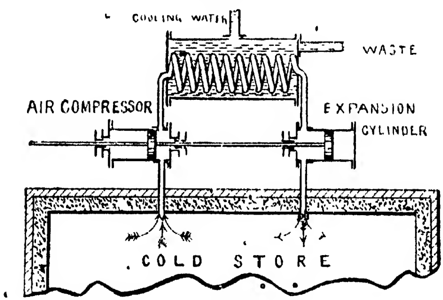



FIG. 1. Diagram illustrating cold-air cycle.

pressures, but the total actual space occupied is no more, as cold-air machines are generally self-contained, there being no additional apparatus required in the form of expansion pipes, condensers, circulating pumps, etc., obviously, therefore, a simple, cold-air system, in which the defects of the old machines have been eliminated, has much to recommend it.

In the early days of cold air it was considered a disadvantage, and uneconomical to reduce air to a very low temperature; but these objections are now entirely overcome by the improved methods of making the cold-air ducts or trunking, by which the loss is reduced to a minimum, and is almost inappreciable.

## VACUUM MACHINES.

Vacuum machines, together with absorption machines, compression machines, and binary, or dual, or mixed absorption and compression machines, all come under the category of vaporisation machines, that is to say, of machines which practically utilise the heat of vaporisation for purposes of refrigeration. In a vacuum machine the refrigerating agent or medium is, as has been already stated, water, its volatilisation at a temperature sufficiently low being effected by the means of a vacuum pump, assisted by sulphuric acid, by which the vapours are absorbed as soon as they are formed, and in this manner rendering the action of the vacuum very effective. The sulphuric acid can be again concentrated for use, and so on *ad infinitum*.

## ABSORPTION MACHINES.

In its action the absorption machine resembles the vacuum machine, with this difference, however, that instead of water, some such liquid as anhydrous ammonia ($NH_3$), capable of evaporating at a low temperature without the assistance of a vacuum, is employed as a refrigerating agent or medium. Instead of sulphuric acid being employed to absorb the vapour, water is employed for that purpose, and from this water the vapour is again separated by distillation and is liquefied by the pressure which takes place in the still, and by the action of the condensing water. (See diagram, Fig. 2.)

In this manner absorption machines can be operated continuously, the ammonia solution or *aqua ammonia* being passed into a still or generator, usually heated by a steam coil or worm, and the ammonia vapour being conducted thence to a condenser in which it is cooled and becomes liquefied into anhydrous ammonia owing to the pressure due to its own accumulation. The anhydrous ammonia is kept in a liquid ammonia receiver, from which it passes to the coils of the refrigerator wherein it expands or evaporates, effecting an amount of refrigeration corresponding to its heat of vaporisation. After performing

this duty the vapour enters the absorber and is there brought into contact with the weak solution of ammonia coming from the bottom of the still, and is reabsorbed by it with generation of heat, which latter is removed by the cooling water. Both the rich and cold solution of ammonia coming from the absorber and going to the still, as well as the poor and hot solution coming from the still

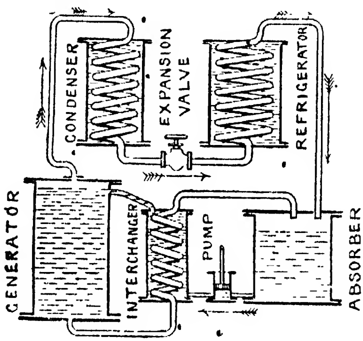



FIG. 2.—Diagram illustrating operation of absorption machine.

and going to the absorber, are passed through a device called an interchanger, by which their temperatures are equalised. The rich ammonia solution is pumped from the absorber into the still or generator.

## THE COMPRESSION MACHINE.

Machines operating on the compression principle (see diagram, Fig. 3) utilise the latent heat of vaporisation of the substances having a low boiling point, and, whatever the refrigerating agent or medium that may be employed, they all practically act in the same manner; that is to say, the vapour or gas due to the expansion or vaporisation of the refrigerating agent or medium, in the refrigerating or expansion coils, passes into a compressor operated by any suitable power by which the gas or vapour is forced into the

coils of the condenser, and is there liquefied by the aid of the cooling water; the liquid thus formed then enters a liquid receiver, from which it is allowed to pass to the refrigerating coils through an expansion or flash valve or cock, by which the desired regulation can be effected. It will be seen that the process is a continuous one, representing a complete cycle of operations, inasmuch as the operating agent or medium periodically returns to its primary condition in a way that will more or less approach reversibility in accordance with the method of working peculiar to each machine.

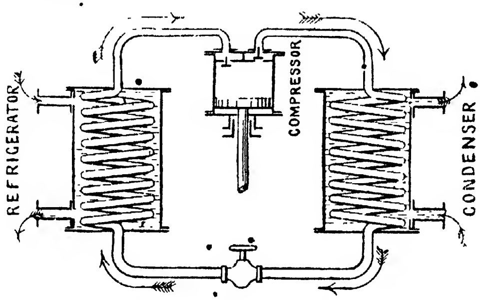



FIG. 3.—Diagram illustrating cycle wherein a volatile liquid and compression are employed.

A perfect reversible compression system comprises the following changes, viz.: An isothermal change due to the vaporisation or gasification of the refrigerating agent or medium at the constant temperature of the refrigerator; an adiabatic change, caused by the compression of the vapour or gas without the addition of heat; a second isothermal change, due to the condensation of the compressed gas or vapour at the constant temperature of the condenser; and, finally, a second adiabatic change, owing to the temperature of the liquid being reduced from that of the condenser to that of the refrigerator by a portion of the liquid being vaporised or gasified, and performing work by moving a piston, thus once more returning the refrigerating

medium or agent to its primary state, and thereby completing the cycle. It is presumed that the above changes take place in such a manner that the transfers of heat follow infinitesimal variations in temperature only, and the changes in volume occur in connection with infinitesimal variations of pressure. The changes can be likewise carried out in the obverse direction, the cycle being therefore a reversible one, and a refrigerating machine, which, it may here be observed, is the exact obverse to a heat engine, operated on this plan, will give as economical results as it is possible to obtain in practice.

For this reason it has been observed by Professor J. E. Siebel that the heat H, removed by a refrigerating apparatus operated strictly on the above-mentioned bases, has a certain and well-defined relation to the work or mechanical power, W, required to lift the same in the cycle of operation. If, in a refrigerating machine so operated, $t_1$ is the temperature of the condenser and $t_0$ the temperature of the refrigerator ($T_1$ and $T_0$ designating the corresponding absolute temperatures), thermodynamics teach us that the following relations exist:—

$$\frac{H}{W} = \frac{t_0 + 460}{t_1 - t_0} = \frac{T_1}{T_1 - T_0}$$

Thermodynamically speaking, says the same authority, there should be no difference in economy on account of the nature of the circulating fluid if a perfect cycle of operation was carried out; but practically, this is not done. In all compression machines, the fourth operation, the reduction of the temperature of the liquid while doing work, is not carried out, but the liquid is cooled at the expense of the refrigeration of the system. No work is attempted, as the amount obtainable would not be in proportion to the expense involved in procuring the same.

The value of a circulating medium, it will be seen, is dependent upon its latent heat of vaporisation per pound, inasmuch as this quality governs its refrigerating effect. Regarding the choice of the circulating medium or agent, therefore, the above point must be taken into consideration, as well as the fact that the size of the compressor depends on the number of cubic feet of vapour that must

be taken in to produce a certain amount of refrigeration, and that the strength of its parts will depend on the pressure of the circulating medium. Also that the loss of refrigeration, on account of cooling the liquid circulating medium, depends on the specific heat of the liquid as compared with the heat of volatilisation.

From the following table it will be seen that with ammonia the loss due to the cooling of the liquid, as shown in percentages for every degree difference in temperature of condenser and refrigerator, is less than in the case of other liquids, and total refrigerating effect per pound of liquid is largest, thus readily accounting for the preference generally given to ammonia as the circulating medium or agent. The only advantage possessed by sulphurous acid is the lower pressure of its vapour, and that of carbonic acid the smaller size of compressor necessary; the loss due to heating of liquid is very large in the latter case.

TABLE OF QUALITIES OF PRINCIPAL LIQUIDS EMPLOYED IN REFRIGERATION.—(*Siebel.*)

| | Pressure in lbs. per square inch, at 0° F. | Heat of Vaporisation per lb., at 0° F. | Volume cubic feet per lb., at 0° F. | Specific Heat of Liquid. | Heat of Vaporisation per cubic foot. | Relative Volume of Compressor for Equal Refrigeration. | Loss due to Cooling Liquid. |
|---|---|---|---|---|---|---|---|
| | | | | | | | Per cent. |
| Sulphurous Acid.. | 10 | 171·2 | 7·35 | 0·41 | 23·3 | 61·70 | 0·24 |
| Carbonic Acid .. | 310 | 123·2 | 0·277 | 1·00 | 447· | 3·24 | 0·81 |
| Ammonia.. .. | 30 | 555·5 | 9·10 | 1·02 | 61·7 | 23·3 | 0·18 |

THE APPLICATION OF THE ENTROPY, OR THETA-PHI, DIAGRAM TO REFRIGERATING MACHINES.

Entropy is the co-ordinate with the temperature of energy, that is to say, length on a diagram, the area of which is energy in heat-units, and the height of which is

absolute temperature; the abscissæ being the quotients found by the division of the heat quantity by the absolute temperature. Absolute temperature is denoted by the Greek letter *theta*, and entropy by the Greek letter *phi*, hence the temperature-entropy diagram is generally called the theta-phi ($\theta$, $\phi$) diagram.

In the case of an indicator diagram the co-ordinates are pressure and volume, the work done per stroke in foot-pounds being represented by the area. The theta-phi diagram represents the heat units as converted into work per pound of the working fluid, the area representing a quantity of heat in heat units, the vertical ordinates absolute temperatures, and the horizontal ordinates the quantity known as entropy. The special applicability of entropy diagrams to refrigeration was pointed out in 1892 by an American engineer, Mr. George Richmond, and they have also been used by Professor Linde for a considerable time past.

The following application of the entropy diagram to refrigerators is abstracted from a useful little work (to which the reader is referred for fuller information on the subject) by Henry A. Golding, A.M.I.M.E., on "The Theta-phi Diagram," published by the Technical Publishing Co., Ltd., Manchester: "The cycle of operations in refrigerators is exactly the reverse of that in the Carnot hot-air engine. Instead of taking in heat at a high temperature $\tau_1$, and transforming part of it into work, and rejecting the remainder at a lower temperature $\tau_2$, as in the heat-engine, the working substance in the refrigerator receives its heat at the lower temperature $\tau_2$, and discharges it at a higher temperature $\tau_1$, the extra energy required being obtained from external work done on the gas. The theoretically perfect cycle that is reversible is shown in Fig. 4 with pressure-volume ordinates, and in Fig. 5 with temperature-entropy ordinates. The first stage of the cycle, A to B, consists of the adiabatic expansion of a certain quantity of air; the temperature falling from $\tau_1$ to $\tau_2$. From B to C the expansion is continued isothermally at constant temperature $\tau_2$, the air receiving heat from the body which it is desired to cool, the amount of heat abstracted being equal to the area EBCF (Fig. 5). Compression commences

at C, and is at first carried on adiabatically at constant entropy (or isentropically) from C to D, the temperature rising from $\tau_2$ to $\tau_1$, and is finally completed by isothermal compression from D to A, at constant temperature $\tau_1$, a quantity of heat being rejected to the water-jacket equal

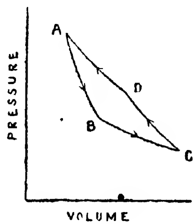



FIG. 4.—Diagram showing Theoretically Perfect Reversible Cycle, with Pressure Volume Ordinates.

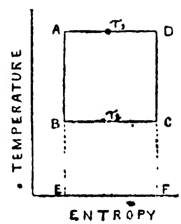



FIG. 5.—Diagram showing Theoretically Perfect Reversible Cycle, with Temperature-Entropy Ordinates.

to FDAE. The heat expended in the process is the equivalent of the work done on the gas, and is equal to the area ABCD in both diagrams. The heat absorbed from the substance to be cooled is equal to the rectangle EBCF (Fig. 5), and the efficiency, therefore (in its thermodynamic sense), is equal to the ratio—

$$\frac{\text{EBCF}}{\text{ABCD}} = \frac{\tau_2}{\tau_1 - \tau_2}$$

It is thus seen clearly how the efficiency is increased by reducing the difference of temperature between $\tau_1$ and $\tau_2$, and as the ratio—

$$\frac{\tau_2}{\tau_1 - \tau_2}$$

may sometimes be greater than unity, it is better known as "the coefficient of performance" (see Howard Lectures, by Professor Ewing, on "The Mechanical Production of Cold," Society of Arts, 1897).

The series of operations in air refrigerators with an open cycle is somewhat different, and is shown in Figs. 6 and 7.

In this case the air is taken from the cold room, and compressed adiabatically from A to B. It is then cooled at constant pressure, the temperature falling from B to C (Fig. 7), and contracting in volume from B to C (Fig. 6), after which it is passed into the expansion cylinder, where it expands adiabatically from C to D, and is discharged to the cold room again. The work done on the air in the compression cylinder is equal to the area EBAF (Fig. 6), or GCBH (Fig. 7), and that done by the air in the expansion cylinder is equal to ECDF (Fig. 6), or GDAH (Fig. 7); so that the net external work required is the difference of these

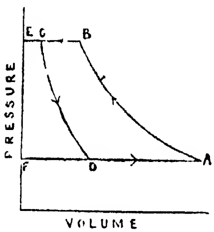



FIG. 6.—Diagram showing Operations in Air Refrigerators with Open Cycle.

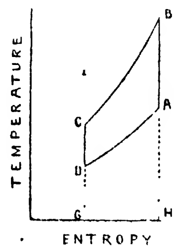



FIG. 7.—Diagram showing Operations in Air Refrigerators with Open Cycle.

two quantities, represented by the area enclosed by ABCD in both diagrams. The efficiency of the process will be represented by the ratio of the two areas—

$$\frac{ECDF}{ECAF} \text{ (Fig. 6)}$$

but, as AB and CD are similar adiabatic curves, this will be equal to the ratio—

$$\frac{EC}{EB} \text{ or } \frac{FD}{FA}$$

The following brief extracts from a paper on "The Theory and Practice of Mechanical Refrigeration," by Mr. T. R. Murray, Wh.Sc., read before the Institution of Engineers and Shipbuilders, Scotland, in December, 1897, will be of interest:—The entropy diagram (Fig. 8) shows an

example of an application to the cold-air cycle, the air being taken in at a temperature $t_1$ of 18° Fahr., the temperature of the refrigeration chamber, and rejected at a temperature $t_2$ of 70° Fahr., which is the temperature of the air after being cooled by the cooling water; the temperature at which the cold air is discharged into the chamber to be taken as − 85° Fahr., and the highest temperature to which it is heated in compression to be taken as 250° Fahr. Considering the machine to be theoretically perfect, then

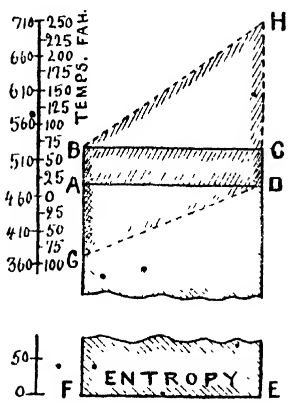



FIG. 8.—Entropy Diagram, showing Application to the Cold-air Cycle.

the diagram ABCD is obtained, in which D to C is the rise of temperature of the air during compression from 18° Fahr. to 70° Fahr.; CB represents the removal of heat in the cooler; B to A represents the cooling in expansion cylinder; and A to D, the collection of heat in the refrigerated chamber. The proportions of the areas ABCD and ADEF represent the proportion of work done to the refrigeration produced. The rectangle AE will be found to be 9·19 times the rectangle BD. In the working cycle, where the air is raised to 250° Fahr. in the compressor, this will be represented on the diagram by point H, and the fall in

temperature during cooling by HB. The temperature being again lowered in expansion cylinder to $-85°$ Fahr., is represented by the vertical line BG, and the collection of heat in the chamber by GD. The diagram of work is now BHDG; which is about 3·75 times the theoretical amount, and when compared with the refrigeration done, now represented by area GDEF, gives an efficiency of only a little over 2. Losses by friction, moisture, etc., reduce this in practice to a little over $\frac{3}{4}$.

Fig. 9 is an entropy diagram for 1 lb. of saturated

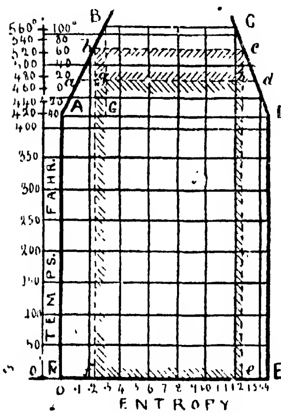


FIG. 9.—Entropy Diagram for 1 lb. of Saturated Ammonia Vapour from $-40°$ to $+100°$ Fahr.

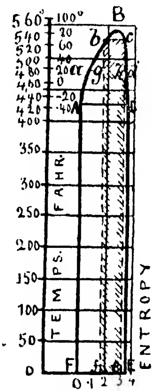


FIG. 10.—Entropy Diagram for 1 lb. of Saturated Carbonic Acid Vapour from $-40°$ to $+100°$ Fahr.

ammonia vapour, from the temperature of $-40°$ Fahr. to $+100°$ Fahr. FE is the basis line, the temperature at this point being absolute zero, $-460°$ Fahr.; A, the absolute temperature at $-40°$ Fahr. $= 420°$ Fahr. $= T_1$.; B, the absolute temperature at, $+100°$ Fahr. $= 560°$ Fahr. $= T_2$; AD = the entropy at $T_1$; and considering that a unit weight of ammonia, say 1 lb. is being dealt with, the length AD can be determined by taking $\frac{L}{T} = \frac{603·45}{420} = 1·436$. In

the same way, $BC = \frac{L_2}{T_2} - 0{\cdot}922$. The point G has still to be determined in order to find the position of point B. Considering, however, that DC represents the compression in compressor, CB the giving out of heat to the condenser, BA the expansion through the orifice of expansion valve, and AD the taking in of heat in the refrigerator, it will be understood that AG really represents the entropy of the liquid heat carried into the refrigerator; and its length may be found by the expression $AG = c \log_e \frac{T_2}{T_1}$, where c = mean specific heat of liquid between $T_1$ and $T_2$. A simpler formula is $AG = \frac{h}{\frac{T_1 + T_2}{2}}$, where h = liquid-heat $T_2$ – liquid heat $T_1$.

By calculating these values for various temperatures between $T_1$ and $T_2$, the points through which to draw the line BA are found. For ammonia it will be found to be practically a straight line, so that it is quite near enough to find the point B only and draw a straight line between A and B. By plotting as abscissæ the values of the entropy of the latent heat at same temperatures, the curve CD will be formed.

Fig. 10 is an entropy diagram for 1 lb. of saturated carbonic acid vapour from the temperature of $-40°$ Fahr. to $+100°$ Fahr., the same construction also applying in this case, but the formation being a continuous curve with a rounded top. To find the efficiency, by means of these diagrams, of a machine working with the same temperatures $T_1$ and $T_2$ as taken with the cold-air cycle, and considering, in the first place, the cycle as being the Carnot or perfect one, compression and expansion will both be adiabatic, therefore they will be represented by vertical lines, and the giving up of heat to the condenser, as well as the collection of same in the refrigerator, being isothermal, then will be shown as horizontal lines. Draw horizontals *a d* and *b c*, and verticals *b g f* and *c h e*. Then the area *b h* will represent the work of the compressor, and the area *g e* the refrigeration done,

These equal respectively $bc \times T_2 - T_1$, and $be \times T_1$. The efficiency will therefore $= \dfrac{be \times T_1}{be \times (T_2 - T_1)} = 9{\cdot}19$ as before.

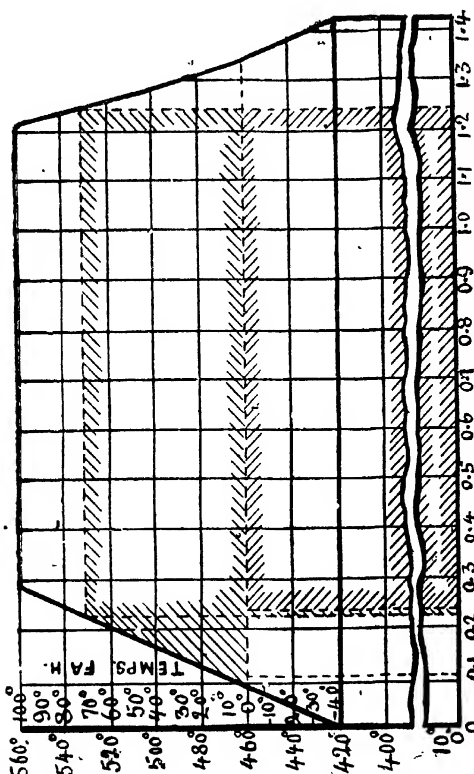



FIG. 11.—Entropy Diagram, showing Working Cycle for 1 lb. of Saturated Ammonia Vapour from −40° to +100° Fahr.

In considering how nearly the actual working cycle approaches the above in practice, it must first be remembered

that the cooling agent simply circulates in pipes through the chambers being cooled, and must of necessity be colder in order to secure a transference of heat. The difference in temperature depends on the cooling surface, or length of

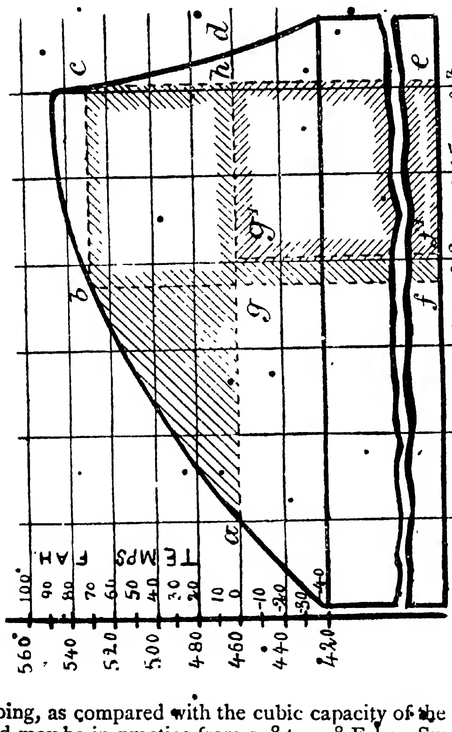



FIG. 12.—Entropy Diagram, showing Working Cycle for 1 lb. of Saturated Carbonic Acid Vapour from −40° to +100° Fahr.

piping, as compared with the cubic capacity of the chamber, and may be in practice from 10° to 25° Fahr. Suppose that allowance be made for a difference of 18° Fahr., then the lower temperature $T_1$ will correspond to 0° Fahr. Again, the working cycle falls away from the Carnot cycle in not being

reversible, owing to expansion taking place through a small orifice instead of by means of an expansion cylinder. Thus the liquid carries a certain amount of heat into the refrigerator, which goes to heat up the expanded gas, rendering part of it unavailable for refrigeration. The amount of this liquid heat varies for each agent, and the entropy diagrams, Figs. 11 and 12, to a larger scale, show the working cycle in each case. In these, the areas $a g b$ represent the additional work that the use of an expansion cycle would have obviated. The heat which ought to have been spent in producing this work is carried by the liquid into the refrigerator, and this therefore falls to be deducted from the refrigeration done, so that the latter is now represented by the area $g_1 h e f_1$, being less than before by the rectangle $g f_1$, which is equal to area $a g b$.

### Comparative Efficiency of Refrigerating Machines.

Professor Ewing estimates the efficiency of the absorption machine at from two and a half to three times that of the cold-air machine, and the efficiency of the vapour-compression machine at from five to six times that of the cold-air machine, and from two and a half to three times that of the absorption machine.

In comparing one system with another, the theoretical values obtained at the machines are not sufficient, as the combined losses in piping, brine cooling, circulating pumps, fans, and any other auxiliary apparatus, must be considered, and only the actual net useful duty performed taken into account. And further, an amount must be added to the capital interest in a plant for recharging with gas (except air machines), including incidentals such as calcium chloride and other items necessary to the system.

Refrigerating machines, to be efficient, must be efficient when working in hot weather or tropical climates. Some systems fall off considerably when the cooling water is about 60° Fahr., and the atmosphere above 70° Fahr., and in some, the cost of working is so high under tropical conditions as to render their use almost prohibitive. The cold-air system does not fall off in the same ratio, and for many purposes is the most economical. All the losses under this system are in the machine, as the air after leaving the

machine does not pass through any secondary process, but is conducted direct to the storage or cooling chamber without the use of brine, circulation pumps, fans, etc.

RATIO OF PRESSURE OF $SO_2$, $NH_3$, and $CO_2$.

(*From Landolt & Bornstein's Physico-Chemical Tables, Lister & Co., Ltd., Catalogue.*)

| Temperature in Degrees Fahr. | Pressure expressed in pounds per square inch. | | |
|---|---|---|---|
| | Sulphurous Acid. $SO_2$. | Ammonia. $NH_3$ | Carbonic Acid. $CO_2$. |
| −4 | — | 12 | 276 |
| +5 | — | 18 | 325 |
| 14 | 0 | 27 | 374 |
| 23 | 4 | 35 | 435 |
| 32 | 8 | 46 | 502 |
| 41 | 11 | 59 | 566 |
| 50 | 18 | 73 | 660 |
| 59 | 25 | 90 | 750 |
| 68 | 32 | 108 | 840 |
| 77 | 41 | 129 | 950 |
| 86 | 51 | 152 | 1,060 |
| 95 | 62 | 180 | 1,280 |
| 104 | 75 | 208 | 1,320 |

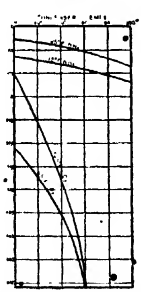


FIG. 13.—Diagram showing Loss of Efficiency with $NH_3$ and $CO_2$ owing to use of Expansion Valve.—(*Murray, Inst. Engrs. and Shipbuilders, Scotland*, 1897.)

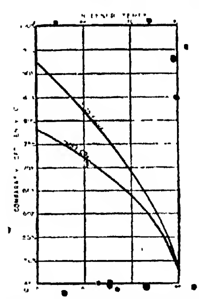


FIG. 14.—Diagram showing Percentage of Efficiency of Working Cycle of $CO_2$ as compared with $NH_3$.—(*Murray, Inst. Engrs. and Shipbuilders, Scotland*, 1897.)

### Results of Test Experiments with Cold-air Machines.

| | Haslam.* | Bell-Coleman.† | Cole's "Arctic"‡ No. 4 Size. | Cole's "Arctic"‡ No. 1 Size. |
|---|---|---|---|---|
| Diameter of comp. cy. in ins. .. | 25½ (2 cy.) | 28 | 11 | 6¾ |
| Diameter of exp. cy. in ins.. .. | 19½ ,, | 21 | 9 | 5¼ |
| Stroke of each .. .. .. | 36 | 24 | 12 | 8 |
| Revs. per minute .. .. .. | 72 | 63·2 | 96 | 160 |
| Air pres. in receiver (abs.) in lbs. per sq. in... .. .. .. | 64 | 61 | 65 | 75 |
| Temp. of air entering comp. cy. (cont. vapour up to 88 per cent. of sat.) in deg. Fahr. .. .. | — | 65·5 | 48 | 46 |
| Temp. of comp. air admitted to exp. cy., Fahr. .. .. .. | — | — | 35 | — |
| Temp. of air after expansion, Fahr. | −85 | −52 | −81 | −98 |
| Init. temp. of cooling water, Fahr. | - - | — | 62 | 41 |
| I.H.P. in comp. cy... .. .. | 346·4 | 124·5 | 14·5 | 3·28 |
| I. H.P. in exp. cy. .. .. .. | 176·2 | 58·5 | 7·8 | 1·68 |
| Per cent. of I. H.P. of comp. retained in expander .. .. .. | 51 | 47 | 54 | 51 |

### Effective Cooling Power obtainable from the expenditure of one pound of Steam in Theoretically Perfect Machines.—(*Tuxen & Hammerich's Cat.*)

| | | |
|---|---|---|
| Ammonia by the absorption system. Thermal Units | 294 | equal to 24 lbs. of ice per lb. of coal consumed. |
| Carbonic Anhydride ... | 652 | equal to 26 lbs. of ice per lb. of coal consumed. |
| Ammonia by the compression system ... ... | 978 | equal to 40 lbs. of ice per lb. of coal consumed. |

* "Proceedings, Manchester Society of Engineers," 1894.
† Prof. Schroeter, "Untersuchungen an Kaeltemaschieren Verschiedener Systeme," 1881.
‡ A. J. Wallis-Tayler, A.M.I.C.E., 1902.

## Tests of Ammonia and Carbonic Acid Machines.

(*Schroeter, Experimental Refrigerating Station, Munich, Germany.*)

| | Ammonia Machine. | | | | Carbonic Acid Machine.* | | | |
|---|---|---|---|---|---|---|---|---|
| No. of Test— | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Temperature in brine tank, degrees Celsius | −6·1 | −6·4 | −6·4 | −4·8 | −4·0 | −4·8 | −4·8 | −6·7 |
| Temperature in condenser, degrees Celsius | 21·4 | 21·4 | 21·4 | 34·9 | 20·0 | 21·2 | 22·2 | 30 |
| Temperature before expansion valve, degrees Celsius | −6·7 | 11·6 | 18·4 | 28·3 | −7·9 | 10·0 | 16·8 | 28·8 |
| Refrigeration per hour, per horse power of steam-engine in calories . . | 3897 | 3636 | 3508 | 2237 | 3832 | 3178 | 2867 | 1477 |

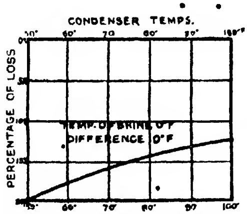



FIG. 15.—Diagram showing Loss of Efficiency with Brine Circulation compared with Direct Expansion of $NH_3$.—(*Murray, Inst. Engrs. and Shipbuilders, Scotland*, 1897.)

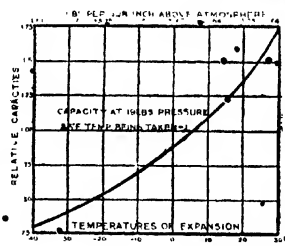



FIG. 16.—Diagram showing Relative Compressor Capacity with $NH_3$ at various Expansion Pressures and Temperatures.—(*Murray, Inst. Engrs. and Shipbuilders, Scotland*, 1897.)

* Dr. Mollier has since proved these results to be incorrect. See "Zeitschrift für Die Gesammte Kalte Industrie."

# CRITICAL POINT FOR CARBONIC ACID, $CO_2$.

The critical point or temperature above which carbonic acid cannot be caused to change from a gaseous to a liquid

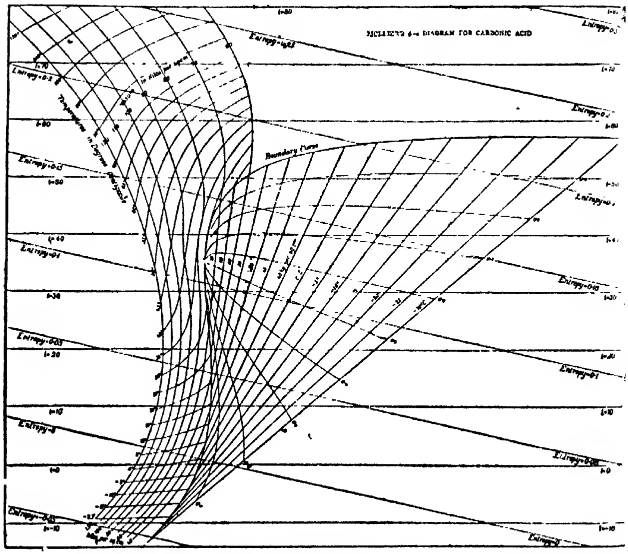


FIG. 16A—Theta-phi Diagram for Carbonic Acid. Metric Units being employed.—(*Dr. Mollier.*)

condition is 88·43°, and the critical pressure 1071 lbs. per sq. in. On approaching the critical point or temperature

| | Tempe-rature. | Pressure in lbs. per sq. in. | Latent heat B.T.U. | Volume of lb. in cub. ft. | Volume per 1000 B.T.U. of refrigeration. |
|---|---|---|---|---|---|
| Water .. .. | 32° F. | 0·085 | 1092 | 3416 | 3129 |
| Sulphurous acid | 32° F. | 22·50 | 164 2 | 3 4 | 20·71 |
| Ammonia .. | 32° F. | 61·80 | 568 | 4·8 | 8·45 |
| Carbonic acid .. | 32° F. | 535·00 | 99·8 | 0·17 | 1 703 |

NOTE.—The volume swept out by the pump is comparatively trifling.

the amount of the latent heat decreases very rapidly proportionately to the liquid heat, consequently with cooling water at high temperatures, such as are only available in tropical countries, considerable loss of efficiency is experienced.

The critical points for ammonia and sulphurous acid are so high (266·0° Fahr. and 312·8° Fahr. respectively), as to be outside the ranges of temperature met with in refrigerating plants. The critical pressures are 1624·0 lbs. per sq. in. for $NH_3$, and 1159·6 lbs. per sq. in. for $SO_2$.

Choice of a liquid for use in a compression machine depends firstly upon thermodynamic, and secondly upon practical considerations. The table on p. 24 by Prof. G. J. Wells ("Proceedings, Inst. Marine Engineers, 1913–14") illustrates some of these points in a clear, concise form.

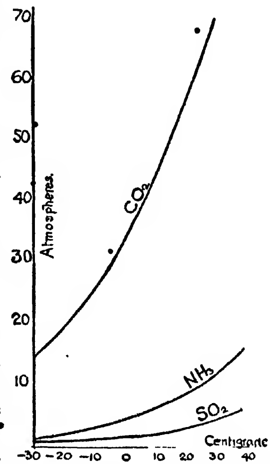



FIG. 16B.—Diagram contrasting physically the properties of the three most used substances as regards pressures.—(*Prof. G. J. Wells, "Proceedings, Inst. Marine Engrs.*, 1913–14.")

THERMO-DYNAMIC LOSSES PECULIAR TO REFRIGERANTS.

(*J. Wemyss Anderson, M.E., "Proceedings, Inst.M.E.*, 1912.")

| Refrigerant. | Latent heat $L_2$ | Liquid heat $S_1 - S_2$ | Refrigerating effect. | Percentage loss $\frac{(S_1 - S_2)100}{L_2}$ |
|---|---|---|---|---|
| $CO_2$ | 110·65 | 32·08 | 78 57 | 29·0 |
| $NH_3$ | 577·40 | 58·50 | 518·9 | 10·1 |
| $SO_2$ | 168·18 | 17·27 | 150·9 | 10 28 |

Upper and lower temperatures 68° F. and 14° F. respectively.

This loss tells very heavily against $CO_2$. If the upper temp. limit had been taken at 86° Fahr. instead of 68° Fahr. the comparison would be still more unfavourable to $CO_2$.

## The Production of very Low Temperatures.

The idea of self-intensive refrigeration, or the regenerative process, seems to have occurred to Siemens, Coleman, Solway, and others many years ago, the first-named having applied for a patent in Germany for such a process as long ago as 1857; and in 1885 the latter patented a similar device and made an apparatus by means of which, however, he was only able to obtain a temperature as low as $-140°$ Fahr., and was not successful in liquefying air. The first perfect self-intensive refrigerating methods are due to Professor Linde and Dr. William Hampson.

The methods primarily employed for the production of intense cold were arranged to operate upon what is known as the cascade system; that is to say, carbonic acid, methyl chloride, nitrous oxide, or any other gas capable of being easily liquefied, is first compressed by a pump, then cooled by water, and finally allowed to pass through a contracted orifice or expansion valve, at lower pressure and reduced to a temperature of, say for instance $-110°$ Fahr., and back again to the compression pump,—in fact, a precisely similar cycle to that of the ammonia compression machine. The low temperature liquid and vapour thus produced then performs a second cycle, taking the place which water takes in the first, and is used to effect the cooling and condensation of a gas of a more volatile nature, such as ethylene, which latter, on passing the orifice or expansion valve, liquefies and vaporises at a still lower temperature, of, say, about $-155°$ Fahr., the exact degree varying according to the pressure maintained on the suction side of the compressor pump. By the ethylene, compressed air or oxygen is cooled in a like manner, and the pressure of the liquid air or oxygen being reduced by passing through an expansion valve, becomes partly vaporised by its own heat, that portion remaining a liquid under atmospheric pressure being reduced to the boiling point of air.

In the self-intensive, or regenerative, method of producing very low temperatures, only one circuit of gas is required, viz. that of the air to be liquefied. This air, starting at an ordinary temperature, with the assistance of only water as a refrigerant, lowers by degrees its own temperature of expansion, by returning over the coils of compressed gas

in the above-mentioned manner, until it reaches the boiling point of air, the liquid then commencing to collect at the pressure of the atmosphere.

The improved apparatus of Dr. Hampson is founded on the well-known fact that any gas, when expanding through a small aperture, will perform such work upon itself as to effect a reduction of temperature, and this effect with air, although not large, is still appreciable. The whole of the gas expanded is used to lower, to a small extent, the temperature of the gas passing to the expansion aperture. This results in the gas expanded being somewhat lower in temperature than that previously expanded, and consequently the succeeding gas is cooled to a further reduced temperature, proceeding thus until the gas attains such a temperature that it commences to liquefy, or until such time as the removal of the heat within the apparatus becomes counterbalanced by the access of heat from the exterior thereof.

The apparatus employed is mainly composed of a series of long, well-insulated, fine copper coils, through which the gas passes to the expansion valve, the arrangement being such that the expanded gas has to flow over the entire external surface of the coils before being removed, so as to abstract as much heat as practicable from the entering gas.

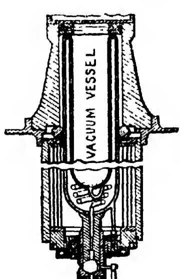



FIG. 17.—Diagram showing Hampson's Apparatus for the Production of very Low Temperatures.

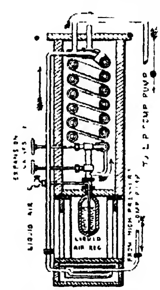



FIG. 18.—Diagram showing Linde's Apparatus for the Production of very Low Temperatures.

## CAPACITY OF REFRIGERATING MACHINES.

Refrigerating machines are rated in two ways, viz. ice-making capacity, or tons of ice they will produce in one

day of twenty-four hours; and refrigerating capacity, or cooling work done by one ton of ice melting per day of twenty-four hours. Roughly, the first or ice-making capacity of a machine may be taken to be about one-half of the refrigerating capacity. This, however, is only an approximation, as the tons of ice a refrigerating machine is capable of making depends upon the initial temperature of the water to be frozen. The unit of capacity is one ton of ice made from water at 32° Fahr. into ice at 32° Fahr. per day, which, according to practice here, is equal to 318,080 lbs. of water cooled one degree, or to 318,080 heat units or thermal units; and, according to American practice, is equal to 284,000 lbs. of water cooled one degree, or 284,000 heat units or thermal units; and this is the tonnage basis for refrigerating capacity as well as for ice-making capacity when ice is made from water at 32° Fahr. The difference between English and American practice is due to 2240 lbs. being taken to the ton in the former, and 2000 lbs. in the latter case.

The real ice-making capacity of a machine is dependent upon the temperature of the water to be frozen, and is calculated as follows: 1 lb. of ice in melting into water at 32° Fahr. will take up 142 positive units of heat, it follows, therefore, that water at 32° Fahr. will require 142 negative units of heat to make it into ice. Say that if the water to be frozen, for instance, be at a temperature of 72° Fahr., it must first be cooled down to 32° Fahr. before freezing commences; therefore $72° - 32° = 40° + 142 = 182$ heat units per pound of water frozen. Ice made artificially is usually much below 32° Fahr., as the temperature of the bath in which it is made ranges about 20° below freezing point, and consequently this work has also to be added. Taking into account the specific heat of ice, this additional negative heat approximately equals 10 units, which added to $182 = 192$; therefore $\frac{142 \times 100}{192} = 73{\cdot}963$, or nearly 74 per cent. tons of ice made per ton refrigerating capacity. For greater accuracy, allowances must also be made for losses by ice tank and can exposure, wastage, thawing out of moulds, etc., etc.

## Table of Compressor Capacity in Cubic Inches.

(*Norman Selfe, "Machinery for Refrigeration."*)

The tabular number multiplied by strokes per minute and divided by 1,728 gives cubic feet per minute theoretical capacity of the cylinder.

| Cylinder Diameter in inches. | LENGTH OF STROKE IN INCHES. | | | | | | | | | | Cylinder Diameter in inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins | C. Ins. | C. Ins. | C. Ins. | |
| 1 | 0·785 | 1·571 | 2·356 | 3·141 | 3·927 | 4·712 | 5·948 | 6·283 | 7·068 | 7·854 | 1 |
| 1½ | 1·767 | 3·534 | 5·301 | 7·068 | 8·835 | 10·602 | 12·370 | 14·137 | 15·905 | 17·672 | 1½ |
| 2 | 3·141 | 6·283 | 9·425 | 12·566 | 15·705 | 18·849 | 21·991 | 25·132 | 28·274 | 31·416 | 2 |
| 2½ | 4·908 | 9·817 | 14·726 | 19·634 | 24·543 | 29·452 | 34·36 | 39·269 | 44·178 | 49·087 | 2½ |
| 3 | 7·068 | 14·137 | 21·206 | 28·274 | 35·343 | 42·411 | 49·480 | 59·549 | 63·617 | 70·686 | 3 |
| 4 | 12·566 | 25·132 | 37·698 | 50·265 | 62·830 | 75·396 | 87·962 | 100·53 | 113·09 | 125·66 | 4 |
| 5 | 19·635 | 39·270 | 58·905 | 78·540 | 98·175 | 117·81 | 137·44 | 157·08 | 176·71 | 196·35 | 5 |
| 6 | 28·274 | 56·548 | 84·822 | 113·09 | 141·37 | 169·64 | 197·92 | 226·19 | 254·46 | 282·74 | 6 |
| 7 | 38·484 | 76·968 | 115·45 | 153·93 | 192·42 | 230·90 | 269·39 | 307·87 | 346·35 | 384·84 | 7 |
| 8 | 50·265 | 100·53 | 150·79 | 201·06 | 251·32 | 301·59 | 351·85 | 402·12 | 452·38 | 502·65 | 8 |
| 9 | 63·617 | 127·23 | 190·85 | 254·47 | 318·08 | 381·70 | 445·32 | 508·93 | 572·55 | 636·17 | 9 |
| 10 | 78·540 | 157·08 | 235·62 | 314·16 | 392·70 | 471·24 | 549·78 | 628·32 | 706·86 | 785·40 | 10 |

## Table of Compressor Capacity in Cubic Inches.—(*Continued.*)

| Cylinder Diameter in inches. | LENGTH OF STROKE IN INCHES. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Cylinder Diameter in inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | |
| 11 | 95·033 | 190·06 | 285·09 | 380·13 | 475·16 | 570·19 | 665·23 | 760·26 | 855·29 | 950·33 | 11 |
| 12 | 113·09 | 226·18 | 339·27 | 452·36 | 565·45 | 678·54 | 791·63 | 904·72 | 1007·8 | 1120·9 | 12 |
| 13 | 132·73 | 265·46 | 398·19 | 530·92 | 663·65 | 796·38 | 929·11 | 1061·8 | 1194·5 | 1327·2 | 13 |
| 14 | 153·93 | 307·86 | 461·79 | 615·72 | 769·65 | 923·58 | 1077·5 | 1231·4 | 1385·3 | 1539·3 | 14 |
| 15 | 176·71 | 353·42 | 530·13 | 706·84 | 883·55 | 1060·2 | 1236·9 | 1413·6 | 1590·3 | 1767·1 | 15 |
| 16 | 201·01 | 402·12 | 603·18 | 804·24 | 1005·3 | 1206·3 | 1407·4 | 1608·4 | 1809·5 | 2010·6 | 16 |
| 17 | 226·98 | 453·96 | 680·94 | 1134·9 | 907·92 | 1361·8 | 1588·8 | 1815·8 | 2042·8 | 2269·8 | 17 |
| 18 | 254·46 | 508·92 | 763·38 | 1017·8 | 1272·3 | 1526·7 | 1781·2 | 2035·6 | 2290·1 | 2544·6 | 18 |
| 19 | 283·52 | 567·04 | 850·56 | 1134·0 | 1417·6 | 1701·1 | 1984·6 | 2268·1 | 2551·6 | 2835·2 | 19 |
| 20 | 314·16 | 628·32 | 942·48 | 1256·6 | 1570·8 | 1884·9 | 2199·1 | 2513·2 | 2827·4 | 3141·6 | 20 |
| 22 | 330·13 | 760·26 | 1140·4 | 1520·5 | 1900·6 | 2280·8 | 2660·9 | 3041·0 | 3421·1 | 3801·3 | 22 |
| 24 | 452·39 | 904·78 | 1357·1 | 1809·5 | 2261·9 | 2714·3 | 3166·7 | 3619·1 | 4071·5 | 4523·9 | 24 |
| 26 | 530·93 | 1061·8 | 1592·7 | 2123·7 | 2654·6 | 3185·5 | 3716·5 | 4247·4 | 4778·3 | 5309·3 | 26 |
| 28 | 615·75 | 1231·5 | 1847·2 | 2463·0 | 3078·7 | 3694·5 | 4310·2 | 4926·0 | 5541·7 | 6157·5 | 28 |
| 30 | 706·86 | 1413·7 | 2120·5 | 2827·4 | 3534·3 | 4241·1 | 4948·0 | 5654·8 | 6361·7 | 7068·6 | 30 |
| 32 | 804·24 | 1608·4 | 2412·7 | 3216·9 | 4021·2 | 4825·4 | 5629·6 | 6433·9 | 7238·1 | 8042·4 | 32 |
| 34 | 907·92 | 1815·8 | 2723·7 | 3631·6 | 4539·6 | 5447·5 | 6355·4 | 7263·3 | 8171·2 | 9079·2 | 34 |
| 36 | 1017·8 | 2034·1 | 3051·2 | 4068·3 | 5085·4 | 6102·4 | 7119·5 | 8136·6 | 9153·7 | 1017·0 | 36 |

TABLE OF COMPRESSOR CAPACITY IN CUBIC INCHES.—(*Continued.*)

| Cylinder Diameter in inches. | LENGTH OF STROKE IN INCHES. | | | | | | | | | | Cylinder Diameter in inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 20 | 22 | 24 | |
| | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | |
| 1 | 8·639 | 9·425 | 10·110 | 10·995 | 11·781 | 12·566 | 14·137 | 15·708 | 17·279 | 18·846 | 1 |
| 1½ | 9·439 | 21·206 | 22·973 | 24·740 | 26·507 | 28·274 | 31·809 | 35·343 | 38·877 | 42·411 | 1½ |
| 2 | 34·557 | 37·699 | 40·841 | 43·982 | 47·124 | 50·265 | 56·549 | 62·832 | 69·113 | 73·399 | 2 |
| 2½ | 53·995 | 58·904 | 63·813 | 68·721 | 73·630 | 78·539 | 88·356 | 98·174 | 107·90 | 117·81 | 2½ |
| 3 | 77·754 | 84·823 | 91·892 | 98·960 | 106·03 | 113·09 | 127·23 | 141·37 | 155·51 | 169·61 | 3 |
| 4 | 138·22 | 150·79 | 163·36 | 175·92 | 188·49 | 201·05 | 226·19 | 251·32 | 276·55 | 301·58 | 4 |
| 5 | 215·98 | 235·62 | 255·25 | 274·89 | 294·52 | 314·16 | 353·43 | 392·70 | 431·97 | 471·24 | 5 |
| 6 | 311·01 | 339·29 | 367·56 | 365·83 | 424·11 | 452·38 | 508·93 | 565·48 | 622·03 | 678·57 | 6 |
| 7 | 423·32 | 461·81 | 500·29 | 538·77 | 577·26 | 615·74 | 692·71 | 769·68 | 846·65 | 923·61 | 7 |
| 8 | 552·91 | 603·18 | 653·44 | 703·71 | 753·97 | 804·24 | 904·77 | 1005·3 | 1105·8 | 1206·3 | 8 |
| 9 | 699·78 | 763·40 | 827·02 | 890·63 | 954·25 | 1017·8 | 1145·1 | 1272·3 | 1399·5 | 1526·8 | 9 |
| 10 | 863·94 | 942·48 | 1021·0 | 1099·5 | 1178·1 | 1250·6 | 1413·7 | 1570·8 | 1727·8 | 1884·9 | 10 |
| 11 | 1045·3 | 1140·3 | 1235·4 | 1330·4 | 1425·4 | 1520·5 | 1710·5 | 1900·6 | 2090·7 | 2280·7 | 11 |
| 12 | 1233·9 | 1357·1 | 1470·2 | 1583·3 | 1696·4 | 1789 5 | 2035·7 | 2261·9 | 2488·1 | 2714·3 | 12 |
| 13 | 1459·9 | 1592·7 | 1725·5 | 1858·2 | 1980·9 | 2123·7 | 2389·1 | 2654·6 | 2920·1 | 3185·5 | 13 |

TABLE OF COMPRESSOR CAPACITY IN CUBIC INCHES.—(*Continued.*)

| Cylinder Diameter in inches. | LENGTH OF STROKE IN INCHES. | | | | | | | | | | Cylinder Diameter in inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 20 | 22 | 24 | |
| | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | C. Ins. | |
| 14 | 1693·2 | 1847·2 | 2001·1 | 2155·1 | 2309·0 | 2463·0 | 2770·8 | 3078·7 | 3386·6 | 3694·5 | 14 |
| 15 | 1943·8 | 2120·5 | 2297·2 | 2174·0 | 2650·7 | 2827·4 | 3180·8 | 3534·3 | 3887·7 | 4241·1 | 15 |
| 16 | 2211·6 | 2412·7 | 2613·8 | 2814·8 | 3015·9 | 3216·9 | 3619·1 | 4021·2 | 4423·3 | 4825·4 | 16 |
| 17 | 2496·8 | 2723·7 | 2650·7 | 3177·7 | 3404·7 | 3631·6 | 4085·6 | 4539·6 | 4993·5 | 5447·5 | 17 |
| 18 | 2799·0 | 3053·6 | 3308·0 | 3562·5 | 3817·0 | 4071·5 | 4580·4 | 5089·3 | 5598·3 | 6107·2 | 18 |
| 19 | 3118·7 | 3402·3 | 3685·8 | 3969·4 | 4252·9 | 4536·4 | 5103·5 | 5670·5 | 6237·6 | 6804·7 | 19 |
| 20 | 3455·7 | 3769·9 | 4084·0 | 4398·2 | 4712·4 | 5026·5 | 5654·8 | 6283·2 | 6911·5 | 7539·8 | 20 |
| 22 | 4181·4 | 4561·5 | 4941·7 | 5321·8 | 5701·9 | 6082·1 | 6842·3 | 7602·6 | 8362·9 | 9123·1 | 22 |
| 24 | 4976·2 | 5428·6 | 5881·0 | 6333·4 | 6785·8 | 7238·2 | 8143·0 | 9047·8 | 9952·5 | 10857·0 | 24 |
| 26 | 5840·2 | 6371·1 | 6902·0 | 7433·0 | 7963·9 | 8494·8 | 9556·7 | 10618·0 | 11680·0 | 12742·0 | 26 |
| 28 | 6773·2 | 7389·0 | 8004·7 | 8620·5 | 9236·3 | 9852·0 | 11083·0 | 12315·0 | 13546·0 | 14778·0 | 28 |
| 30 | 7775·4 | 8482·3 | 9189·1 | 9896·0 | 10602·0 | 11309·0 | 12723·0 | 14137·0 | 15550·0 | 16964·0 | 30 |
| 32 | 8846·6 | 9650·9 | 10455·0 | 11259·0 | 12063·0 | 12868·0 | 14576·0 | 16085·0 | 17693·0 | 19301·0 | 32 |
| 34 | 9987·1 | 10895·0 | 11802·0 | 12710·0 | 13618·0 | 14526·0 | 13642·0 | 18158·0 | 19974·0 | 21790·0 | 34 |
| 36 | 11187·0 | 12214·0 | 13232·0 | 14240·0 | 15258·0 | 16275·0 | 18311·0 | 20347·0 | 22385·0 | 24418·0 | 36 |

## MEAN PRESSURE OF COMPRESSOR.

The following table from the *De La Vergne* catalogue admits of the mean pressure in the compressor, and indirectly the work of the compressor being approximately ascertained from the refrigerator and condenser pressure and temperature :—

| Condenser Pressure. | | 103 | 115 | 127 | 139 | 153 | 168 | 184 | 200 | 218 |
|---|---|---|---|---|---|---|---|---|---|---|
| Condenser Temperature. | | 65° | 70° | 75° | 80° | 85° | 90° | 95° | 100° | 105° |
| Refrigerator Pressure. | Refrigerator Temperature. | | | | | | | | | |
| 4 | −20° | 41·46 | 43·91 | 46·34 | 48·77 | 51·23 | 53·68 | 56·11 | 58·54 | 60·99 |
| 6 | −15° | 42·72 | 45·38 | 47·90 | 50·74 | 53·40 | 56·08 | 58·86 | 61·40 | 64·08 |
| 9 | −10° | 44·40 | 47·38 | 50·33 | 53·29 | 56·25 | 59·20 | 62·16 | 65·14 | 68·09 |
| 13 | −5° | 45·86 | 49·15 | 52·42 | 55·70 | 58·97 | 62·25 | 65·53 | 68·81 | 72·08 |
| 16 | 0° | 46·94 | 50·56 | 54·16 | 57·78 | 62·40 | 65·00 | 68·62 | 72·22 | 75·84 |
| 20 | 5° | 47·74 | 51·73 | 55·70 | 59·68 | 63·67 | 67·66 | 71·62 | 75·61 | 79·61 |
| 24 | 10° | 48·04 | 52·40 | 56·77 | 61·13 | 65·51 | 69·86 | 74·24 | 78·59 | 82·97 |
| 28 | 15° | 47·88 | 52·67 | 57·44 | 62·23 | 67·02 | 71·81 | 76·60 | 81·39 | 86·18 |
| 33 | 20° | 47·08 | 52·30 | 57·53 | 62·75 | 67·98 | 73·23 | 78·46 | 83·68 | 88·91 |
| 39 | 25° | 45·06 | 51·34 | 57·05 | 62·75 | 68·46 | 74·17 | 79·88 | 85·58 | 91·29 |
| 45 | 30° | 43·16 | 49·71 | 55·92 | 62·14 | 68·35 | 74·56 | 80·77 | 86·98 | 93·19 |
| 51 | 35° | 40·52 | 47·26 | 54·02 | 60·76 | 67·52 | 74·28 | 81·02 | 87·78 | 94·52 |

TABLE GIVING NUMBER OF CUBIC FEET OF GAS THAT MUST BE PUMPED PER MINUTE AT DIFFERENT CONDENSER AND SUCTION PRESSURES TO PRODUCE ONE TON OF REFRIGERATION IN 24 HOURS.

(*Professor Siebel, "Compend of Mechanical Refrigeration."*)

| Temperature of Gas in Degrees Fahr. | Corresponding Suction Pressure. lbs. per sq. in. | Temperature of the Gas in Degrees Fahr. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
| | | Corresponding Condenser Pressure (Gauge) lbs. per square inch. | | | | | | | | |
| | | 103 | 115 | 127 | 139 | 153 | 168 | 181 | 200 | 218 |
| | G. Pres. | | | | | | | | | |
| −27 | 1 | 7·22 | 7·3 | 7·37 | 7·46 | 7·54 | 7·62 | 7·70 | 7·79 | 7·88 |
| −20 | 4 | 5·84 | 5·9 | 5·96 | 6·03 | 6·09 | 6·16 | 6·23 | 6·30 | 6·43 |
| −15 | 6 | 5·35 | 5·4 | 5·46 | 5·52 | 5·58 | 5·64 | 5·70 | 5·77 | 5·83 |
| −10 | 9 | 4·66 | 4·73 | 4·76 | 4·81 | 4·86 | 4·91 | 4·97 | 5·05 | 5·08 |
| −5 | 13 | 4·09 | 4·12 | 4·17 | 4·21 | 4·25 | 4·30 | 4·35 | 4·40 | 4·44 |
| 0 | 16 | 3·59 | 3·63 | 3·66 | 3·70 | 3·74 | 3·78 | 3·83 | 3·87 | 3·91 |
| 5 | 20 | 3·20 | 3·24 | 3·27 | 3·30 | 3·34 | 3·38 | 3·41 | 3·45 | 3·49 |
| 10 | 24 | 2·87 | 2·9 | 2·93 | 2·96 | 2·99 | 3·02 | 3·06 | 3·09 | 3·12 |
| 15 | 28 | 2·59 | 2·61 | 2·65 | 2·68 | 2·71 | 2·73 | 2·76 | 2·80 | 2·82 |
| 20 | 33 | 2·31 | 2·34 | 2·36 | 2·38 | 2·41 | 2·44 | 2·46 | 2·49 | 2·51 |
| 25 | 39 | 2·06 | 2·08 | 2·10 | 2·12 | 2·15 | 2·17 | 2·20 | 2·22 | 2·24 |
| 30 | 45 | 1·85 | 1·87 | 1·89 | 1·91 | 1·93 | 1·95 | 1·97 | 2·00 | 2·01 |
| 35 | 51 | 1·70 | 1·72 | 1·74 | 1·76 | 1·77 | 1·79 | 1·81 | 1·83 | 1·85 |

APPROXIMATE ALLOWANCES PER TON CAPACITY TO BE MADE WHEN SELECTING A MACHINE FOR REFRIGERATING PURPOSES.—(*Triumph Ice Machine Company.*)

Beer wort: 15 barrels per ton on Baudelot cooler. One thousand gallons of sweet water per ton from 70° to 40°. Six beeves, 600 to 700 lbs. each, per ton. Ten to twenty hogs. per ton. One thousand cubic feet of space per ton for small machines up to 2 tons. Four thousand cubic feet of space per ton for machine from 10 to 15 tons. Ten thousand cubic feet of space per ton for larger machines used for general purposes.

The above will serve as a guide, but it must be borne in mind that the climate, construction, and exposure of buildings that are to be refrigerated, character of the insulation, management and method of handling work, all have to be taken into consideration. (See also Section on Cold Storage.)

CONDENSERS.

On the efficiency of the condenser largely depends the economical working of the machine. Condensers are of two kinds or classes, viz. the submerged and the open air, or atmospheric, the latter being the more economical in the matter of cooling water, but occupying the larger amount of space.

According to Professor Siebel, under average conditions (incoming condenser water 70°, and outgoing condenser water 80°, more or less), for each ton of refrigerating capacity (or for one half-ton of ice-making capacity) 40 square feet of condenser surface, corresponding to 64 running feet of 2-inch pipe, and to 90 running feet of $1\frac{1}{4}$-inch pipe, will be required in a submerged condenser. The amount of cooling water used varies from 3 to 7 gallons per minute per ton ice-making capacity in twenty-four hours. The pipe required in an open air condenser is 40 square feet per ton of refrigerating capacity (or for one half-ton of ice-making capacity), equivalent to 64 running feet of 2-inch pipe, or 90 running feet of $1\frac{1}{4}$-inch pipe. The amount of cooling water used is about 50 per cent. less than with condensers of the submerged type.

Double pipe condensers are made which are claimed to possess the best qualities of both submerged and open air condensers. This condenser consists of a coil made up with one pipe inside another of larger diameter, the cooling water circulating through the internal pipe, and the compressed gas in the annular space or clearance between the two pipes. The gas is thus exposed to the action of both cooling water and the atmosphere.

EVAPORATION OF LIQUIDS.—(*Lightfoot.*)

| Liquid or gas. | | Water. | Anhydrous Ammonia. | Sulphuric ether. | Mythylic ether. | Sulphur dioxide. | Pictet's liquid. |
|---|---|---|---|---|---|---|---|
| Specific gravity of vapour, compared with air = 1·000 | | 0·622 | 0·59 | 2·24 | 1·61 | 2·24 | — |
| | | Fahr. | Fahr. | Fahr. | Fahr. | Fahr. | Fahr. |
| Boiling point at atmospheric pressure | | 212° | - 37·3° | 96° | −10·5 | 14° | −2·2° |
| Latent heat of vaporisation at atmospheric pressure | | 966 | 900 | 165 | 473 | 182 | — |
| Absolute vapour tensions in lbs. per square inch at different temperatures. | Fahr. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| | − 40° | — | — | — | — | — | — |
| | − 20° | — | 19·4 | — | 12·0 | 5·7 | 11·6 |
| | 0° | — | 30·0 | 1·5 | 18·7 | 9·8 | 15·4 |
| | + 20° | — | 47·7 | 2·6 | 28·1 | 16·9 | 22·0 |
| | + 32° | 0·089 | 61·5 | 3·6 | 36·0 | 22·7 | 27·0 |
| | + 40° | 0·122 | 73·0 | 4·5 | 42·5 | 27·3 | 31·3 |
| | + 60° | 0·254 | 108·0 | 7·2 | 61·0 | 41·4 | 44·0 |
| | + 80° | 0·503 | 152·4 | 10·9 | 86·1 | 60·2 | 60·0 |
| | 100° | 0·942 | 210·6 | 16·2 | 118·0 | 84·5 | 79·1 |
| | 120° | 1·685 | 283·7 | 23·5 | — | 117·5 | 99·7 |
| | 140° | 2·879 | — | 33·5 | — | — | .. |
| | 160° | 4·731 | — | 45·6 | — | — | — |
| | 180° | 7·511 | — | 62·0 | — | — | — |
| | 200° | 11·526 | — | 81·8 | — | — | — |
| | 212° | 14·7 | — | 96·0 | — | — | — |

TABLE SHOWING PRESSURE AND BOILING POINT OF SOME OF THE LIQUIDS AVAILABLE FOR USE IN REFRIGERATING MACHINES.—(*Ledoux.*)

| Temperature of Ebullition. | Tension of Vapour, in pounds per square inch, above Zero. | | | | | |
|---|---|---|---|---|---|---|
| Deg. Fahr. | Sulphuric Ether. | Sulphur Dioxide. | Ammonia. | Methylic Ether. | Carbonic Acid. | Pictet Fluid. |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| —40 | — | — | 10·22 | — | — | — |
| —31 | — | — | 13·23 | — | — | — |
| —22 | — | 5·56 | 16·95 | 11·15 | — | — |
| —13 | — | 7·23 | 21·51 | 13·85 | 251·6 | — |
| — 4 | 1·30 | 9·27 | 27·04 | 17·06 | 292·9 | 13·5 |
| 5 | 1·70 | 11·76 | 33·67 | 20·84 | 340·1 | 16·2 |
| 14 | 2·19 | 14·75 | 41·58 | 25·27 | 393·4 | 19·3 |
| 23 | 2·79 | 18·31 | 50·91 | 30·41 | 453·4 | 22·9 |
| 32 | 3·55 | 22·53 | 61·85 | 36·34 | 520·4 | 26·9 |
| 41 | 4·45 | 27·48 | 74·55 | 43·13 | 594·8 | 31·2 |
| 50 | 5·54 | 33·26 | 89·21 | 50·84 | 676·9 | 36·2 |
| 59 | 6·84 | 39·93 | 105·99 | 59·56 | 766·9 | 41·7 |
| 68 | 8·38 | 47·62 | 125·08 | 69·35 | 864·9 | 48·1 |
| 77 | 10·19 | 56·39 | 146·64 | 80·28 | 971·1 | 55·6 |
| 86 | 12·31 | 66·37 | 170·83 | 92·41 | 1085·6 | 64·1 |
| 95 | 14·76 | 77·64 | 197·83 | — | 1207·9 | 73·2 |
| 104 | 17·59 | 90·32 | 227·76 | — | 1338·2 | 82·9 |

TABLE OF SPECIFIC GRAVITIES AND PERCENTAGE OF AMMONIA.—(*Carius.*)

| Degrees Beaumé. | Specific Gravity. | Percentage. | Degrees Beaumé. | Specific Gravity. | Percentage. |
|---|---|---|---|---|---|
| 10 | 1·000 | 0 | 21 | 0·9271 | 19·4 |
| 11 | 0·9929 | 1·8 | 22 | 0·921 | 21·4 |
| 12 | 0·9859 | 3·3 | 23 | 0·915 | 23·4 |
| 13 | 0·979 | 5·0 | 24 | 0·909 | 25·3 |
| 14 | 0·9722 | 6·7 | 25 | 0·9032 | 27·7 |
| 15 | 0·9655 | 8·4 | 26* | 0·8974 | 30·1 |
| 16 | 0·9589 | 10·0 | 27 | 0·8917 | 32·5 |
| 17 | 0·9523 | 11·9 | 28 | 0·886 | 35·2 |
| 18 | 0·9459 | 13·7 | 29 | 0·88[illegible] | .. |
| 19 | 0·9395 | 15·5 | 30 | 0·875 | .. |
| 20 | 0·9333 | 17·4 | .. | .. | .. |

* Known by the trade as 29½ per cent.

NOTE.—The specific gravity of pure anhydrous ammonia is ·623.

BOILING POINT, LATENT HEAT, ETC., OF ANHYDROUS AMMONIA.—(*Redwood.*)

| Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Absolute. | Gauge. | | | Absolute. | Gauge. | | | Absolute. | Gauge. | | | Absolute. | Gauge. | | |
| 10·69 | −4·01 | −40·0 | 579·7 | 37·00 | 22·30 | 8·2 | 550·5 | 71·00 | 56·30 | 38·6 | 531·5 | 168·70 | 154·00 | 86·0 | 500·8 |
| 11·30 | −3·70 | −39·0 | 579·1 | 38·55 | 23·85 | 10·0 | 549·3 | 73·00 | 58·30 | 40·0 | 530·6 | 175·70 | 161·00 | 88·5 | 499·5 |
| 12·31 | −2·39 | −35·0 | 576·7 | 39·00 | 24·30 | 10·6 | 549·0 | 74·07 | 59·37 | 41·0 | 530·0 | 182·80 | 168·10 | 93·0 | 498·1 |
| 13·00 | −1·70 | −32·7 | 575·3 | 40·00 | 25·30 | 12·0 | 548·1 | 75·00 | 60·30 | 41·5 | 529·7 | 194·80 | 180·10 | 95·0 | 495·3 |
| 14·13 | −0·57 | −30·0 | 573·7 | 42·30 | 27·50 | 14·0 | 546·8 | 76·00 | 61·30 | 42·2 | 529·2 | 204·70 | 190·00 | 98·0 | 493·3 |
| 14·70 | +0·00 | −28·5 | 572·3 | 42·93 | 28·23 | 15·0 | 546·3 | 78·00 | 63·30 | 43·4 | 528·5 | 215·14 | 200·44 | 100·0 | 491·5 |
| 15·00 | +0·30 | −27·8 | 571·7 | 44·00 | 29·30 | 16·0 | 545·6 | 80·66 | 65·96 | 45·0 | 527·5 | 224·40 | 209·70 | 104·0 | 489·4 |
| 16·17 | 1·47 | −25·0 | 570·7 | 45·00 | 30·30 | 17·0 | 545·0 | 88·96 | 74·26 | 50·0 | 524·3 | 257·20 | 242·50 | 113·0 | 483·4 |
| 16·71 | 2·01 | −22·0 | 568·9 | 46·00 | 31·30 | 18·1 | 544·3 | 92·00 | 77·30 | 51·4 | 523·4 | 293·20 | 278·50 | 122·0 | 476·4 |
| 17·00 | 2·30 | −21·8 | 568·7 | 47·00 | 32·30 | 19·1 | 543·7 | 95·00 | 80·30 | 53·2 | 522·3 | 333·10 | 318·40 | 131·0 | 471·4 |
| 18·45 | 3·75 | −20·0 | 567·7 | 47·95 | 33·25 | 20·0 | 543·1 | 97·93 | 83·23 | 55·0 | 521·1 | 377·20 | 352·50 | 140·0 | 465·4 |
| 19·00 | 4·30 | −18·9 | 567·0 | 49·00 | 34·30 | 21·1 | 542·5 | 100·00 | 85·30 | 56·1 | 520·4 | | | | |
| 20·99 | 6·29 | −15·0 | 564·6 | 50·00 | 35·30 | 22·3 | 541·7 | 104·84 | 90·14 | 59·0 | 518·6 | | | | |
| 21·27 | 6·57 | −13·0 | 563·4 | 50·67 | 35·97 | 23·0 | 541·3 | 107·60 | 92·90 | 60·0 | 517·9 | | | | |
| 22·10 | 7·40 | −12·0 | 562·8 | 51·00 | 36·30 | 23·3 | 541·1 | 110·00 | 95·30 | 61·1 | 517·2 | | | | |
| 22·93 | 8·23 | −11·0 | 562·2 | 52·00 | 37·30 | 24·0 | 540·7 | 115·00 | 100·30 | 63·5 | 515·7 | | | | |
| 23·77 | 9·07 | −10·0 | 561·6 | 53·43 | 38·73 | 25·0 | 540·0 | 118·03 | 103·33 | 65·0 | 515·3 | | | | |

BOILING POINT, LATENT HEAT, ETC., OF ANHYDROUS AMMONIA.—(*Redwood.*) (*Continued.*)

| Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. | Pressure. | | Boiling Point. ° Fahr. | Latent Heat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Absolute. | Gauge. | | | Absolute. | Gauge. | | | Absolute. | Gauge. | | | Absolute. | Gauge. | | |
| 24·56 | 9·86 | −9·0 | 561·0 | 54·00 | 39·30 | 25·5 | 539·7 | 119·70 | 105·00 | 66·0 | 514·1 | | | | |
| 25·32 | 10·62 | −8·0 | 560·4 | 55·00 | 40·30 | 26·3 | 539·3 | 123·59 | 108·89 | 68·0 | 512·8 | | | | |
| 26·08 | 11·38 | −7·0 | 559·8 | 56·00 | 41·30 | 27·1 | 538·7 | 125·20 | 112·50 | 69·0 | 512·2 | | | | |
| 26·84 | 12·14 | −6·0 | 559·2 | | | | | | | | | | | | |
| 27·57 | 12·87 | −5·0 | 558·5 | 57·00 | 42·30 | 28·0 | 538·2 | 127·21 | 114·51 | 70·0 | 511·5 | | | | |
| 28·09 | 13·39 | −4·0 | 557·9 | 58·00 | 43·30 | 28·9 | 537·6 | 138·70 | 124·00 | 74·5 | 508·6 | | | | |
| 28·64 | 13·94 | −3·0 | 557·3 | 59·41 | 44·71 | 30·0 | 536·9 | 141·25 | 127·55 | 75·0 | 508·3 | | | | |
| 29·17 | 14·47 | −2·0 | 556·7 | 60·00 | 45·30 | 30·6 | 536·5 | 144·67 | 129·97 | 77·0 | 507·0 | | | | |
| 29·76 | 15·06 | −1·0 | 556·1 | 61·50 | 46·80 | 32·0 | 535·7 | 149·70 | 135·00 | 78·5 | 506·0 | | | | |
| 30·37 | 15·67 | +0·0 (zero) | 555·5 | 62·00 | 47·30 | 32·3 | 535·5 | 154·11 | 139·41 | 80·0 | 504·7 | | | | |
| 31·00 | 16·30 | +1·4 | 554·6 | 63·00 | 48·30 | 33·0 | 535·0 | 161·70 | 147·00 | 82·5 | 503·5 | | | | |
| 32·00 | 17·30 | 3·5 | 553·4 | 64·00 | 49·30 | 33·7 | 534·6 | 165·70 | 151·00 | 84·5 | 502·1 | | | | |
| 33·66 | 18·96 | 5·0 | 552·4 | 65·93 | 51·23 | 35·0 | 533·8 | 166·70 | 152·00 | 84·9 | 501·8 | | | | |
| 35·00 | 20·30 | 5·9 | 551·9 | 67·00 | 52·30 | 35·8 | 533·3 | 167·86 | 153·16 | 85·4 | 501·6 | | | | |
| 36·00 | 21·30 | 7·0 | 551·2 | 69·00 | 54·30 | 37·2 | 532·4 | 168·30 | 153·60 | 85·7 | 501·2 | | | | |

## Solubility of Ammonia in Water at Different Temperatures.—(*Sims.*)

| Degrees Fahr. | Sb. of $NH_3$ to 1 lb. of Water. | Volume of $NH_3$ in 1 Volume of Water. | Degrees Fahr. | Sb. of $NH_3$ to 1 lb. of Water. | Volume of $NH_3$ in 1 Volume of Water. |
|---|---|---|---|---|---|
| 32·0 | 0·899 | 1,180 | 125·6 | 0·274 | 359 |
| 35·6 | 0·853 | 1,120 | 129·2 | 0·265 | 348 |
| 39·2 | 0·809 | 1,062 | 132·8 | 0·256 | 336 |
| 42·8 | 0·765 | 1,005 | 136·4 | 0·247 | 324 |
| 46·4 | 0·724 | 951 | 140·0 | 0·238 | 312 |
| 50·0 | 0·684 | 898 | 143·6 | 0·229 | 301 |
| 53·6 | 0·646 | 848 | 147·2 | 0·220 | 389 |
| 57·2 | 0·611 | 802 | 150·8 | 0·211 | 277 |
| 60·8 | 0·578 | 759 | 154·4 | 0·202 | 265 |
| 64·4 | 0·546 | 717 | 158·0 | 0·194 | 254 |
| 68·0 | 0·518 | 683 | 161·6 | 0·186 | 244 |
| 71·6 | 0·490 | 643 | 165·2 | 0·178 | 234 |
| 75·2 | 0·467 | 613 | 168·8 | 0·170 | 223 |
| 78·8 | 0·446 | 585 | 172·4 | 0·162 | 212 |
| 82·4 | 0·426 | 559 | 176·0 | 0·154 | 202 |
| 86·0 | 0·408 | 530 | 179·6 | 0·146 | 192 |
| 89·2 | 0·393 | 516 | 183·2 | 0·138 | 181 |
| 93·2 | 0·378 | 496 | 186·8 | 0·130 | 170 |
| 96·8 | 0·363 | 478 | 190·4 | 0·122 | 160 |
| 100·4 | 0·350 | 459 | 194·0 | 0·114 | 149 |
| 104·0 | 0·338 | 444 | 197·6 | 0·106 | 139 |
| 107·6 | 0·326 | 428 | 201·2 | 0·098 | 128 |
| 111·2 | 0·315 | 414 | 204·8 | 0·090 | 118 |
| 114·8 | 0·303 | 399 | 208·4 | 0·082 | 107 |
| 118·4 | 0·294 | 386 | 212·0 | 0·074 | 97 |
| 122·0 | 0·284 | 373 | .. | .. | .. |

## The Forecooler.

This is a supplementary condenser through which the compressed ammonia passes before reaching the main condenser, and cooled by the overflow water from the latter. If composed of one coil, it should be the same size as discharge pipe from compressor; if of a number of coils, the manifold pipe, and the aggregate area openings of small pipes, should be equal to that of the discharge pipe.

## SOLUBILITY OF AMMONIA IN WATER AT DIFFERENT TEMPERATURES AND PRESSURES.—(*Sims.*)

1 lb. of water (also unit volume) absorbs the following quantities of ammonia :—

| Absolute Pressure in lbs. per sq. in. | 32° F. | | 68° F. | | 104° F. | | 212° F. | |
|---|---|---|---|---|---|---|---|---|
| | lbs. | vols. | lbs. | vols. | lbs. | vols. | grms. | vols. |
| 14·67 | 0·899 | 1·180 | 0·518 | 0·683 | 0·338 | 0·443 | 0·074 | 0·97 |
| 15·44 | 0·937 | 1·231 | 0·535 | 0·703 | 0·349 | 0·458 | 0·078 | 0·102 |
| 16·41 | 0·980 | 1·287 | 0·556 | 0·730 | 0·363 | 0·476 | 0·083 | 0·109 |
| 17·37 | 1·029 | 1·351 | 0·574 | 0·754 | 0·378 | 0·496 | 0·088 | 0·115 |
| 18·34 | 1·077 | 1·414 | 0·594 | 0·781 | 0·391 | 0·513 | 0·092 | 0·120 |
| 19·30 | 1·126 | 1·478 | 0·613 | 0·805 | 0·404 | 0·531 | 0·096 | 0·126 |
| 20·27 | 1·177 | 1·548 | 0·632 | 0·830 | 0·414 | 0·543 | 0·101 | 0·132 |
| 21·23 | 1·236 | 1·615 | 0·651 | 0·855 | 0·425 | 0·558 | 0·106 | 0·139 |
| 22·19 | 1·283 | 1·685 | 0·669 | 0·878 | 0·434 | 0·570 | 0·110 | 0·140 |
| 23·16 | 1·336 | 1·754 | 0·685 | 0·894 | 0·445 | 0·584 | 0·115 | 0·151 |
| 24·13 | 1·388 | 1·823 | 0·704 | 0·924 | 0·454 | 0·596 | 0·120 | 0·157 |
| 25·09 | 1·442 | 1·894 | 0·722 | 0·948 | 0·463 | 0·609 | 0·125 | 0·164 |
| 26·06 | 1·496 | 1·965 | 0·741 | 0·973 | 0·472 | 0·619 | 0·130 | 0·170 |
| 27·02 | 1·549 | 2·034 | 0·761 | 0·999 | 0·479 | 0·629 | 0·135 | 0·177 |
| 27·99 | 1·603 | 2·105 | 0·780 | 1·023 | 0·486 | 0·638 | .. | .. |
| 28·95 | 1·656 | 2·175 | 0·801 | 1·052 | 0·493 | 0·647 | .. | .. |
| 30·88 | 1·758 | 2·309 | 0·842 | 1·106 | 0·511 | 0·671 | .. | .. |
| 32·81 | 1·861 | 2·444 | 0·881 | 1·157 | 0·530 | 0·696 | .. | .. |
| 34·74 | 1·966 | 2·582 | 0·919 | 1·207 | 0·547 | 0·718 | .. | .. |
| 36·67 | 2·070 | 2·718 | 0·955 | 1·254 | 0·565 | 0·742 | .. | .. |
| 38·60 | .. | .. | 0·992 | 1·302 | 0·579 | 0·764 | .. | .. |
| 40·53 | .. | .. | .. | .. | 0·594 | 0·780 | .. | .. |

## SOLUBILITY OF AMMONIA IN WATER AT DIFFERENT TEMPERATURES.—(*Roscoe.*)

| Degrees Celsius. | Degrees Fahrenheit. | lbs. of $NH_3$ to 1 lb. of Water. | Degrees Celsius. | Degrees Fahrenheit. | lbs. of $NH_3$ to 1 lb. of Water. |
|---|---|---|---|---|---|
| 0 | 32·0 | 0·875 | 8 | 46·4 | 0·713 |
| 2 | 35·6 | 0·833 | 10 | 50·0 | 0·679 |
| 4 | 39·2 | 0·792 | 12 | 53·6 | 0·645 |
| 6 | 42·8 | 0·751 | 14 | 57·2 | 0·612 |

## SOLUBILITY OF AMMONIA IN WATER AT DIFFERENT TEMPERATURES.—(*Roscoe.*) (*Continued.*)

| Degrees Celsius. | Degrees Fahrenheit. | lbs of $NH_3$ to 1 lb. of Water. | Degrees Celsius. | Degrees Fahrenheit. | lbs. of $NH_3$ to 1 lb. of Water. |
|---|---|---|---|---|---|
| 16 | 60·8 | 0·582 | 36 | 96·8 | 0·343 |
| 18 | 64·4 | 0·554 | 38 | 100·4 | 0·324 |
| 20 | 68·0 | 0·526 | 40 | 104·0 | 0·307 |
| 22 | 71·6 | 0·499 | 42 | 107·6 | 0·290 |
| 24 | 75·2 | 0·474 | 44 | 111·2 | 0·275 |
| 26 | 78·8 | 0·449 | 46 | 114·8 | 0·259 |
| 28 | 82·4 | 0·426 | 48 | 118·4 | 0·244 |
| 30 | 86·0 | 0·403 | 50 | 122·0 | 0·229 |
| 32 | 89·6 | 0·382 | 52 | 125·6 | 0·214 |
| 34 | 93·2 | 0·362 | 54 | 129·2 | 0·200 |
| | | | 56 | 132·8 | 0·186 |

## STRENGTH OF LIQUOR AMMONIA.

| Percentage of Ammonia by Weight. | Specific Gravity | Degrees Beaumé, Water, 10. |
|---|---|---|
| 0 | 1·000 | 10·0 |
| 2 | 0·986 | 12·0 |
| 4 | 0·979 | 13·0 |
| 6 | 0·972 | 14·0 |
| 8 | 0·966 | 15·0 |
| 10 | 0·960 | 16·0 |
| 12 | 0·953 | 17·1 |
| 14 | 0·945 | 18·3 |
| 16 | 0·938 | 19·5 |
| 18 | 0·931 | 20·7 |
| 20 | 0·925 | 21·7 |
| 22 | 0·919 | 22·8 |
| 24 | 0·913 | 23·9 |
| 26 | 0·907 | 24·8 |
| 28 | 0·902 | 25·7 |
| 30 | 0·897 | 26·6 |
| 32 | 0·892 | 27·5 |
| 34 | 0·888 | 28·4 |
| 36 | 0·884 | 29·3 |
| 38 | 0·880 | 30·2 |

YIELD, ETC., OF ANHYDROUS AMMONIA FROM AMMONIA SOLUTIONS.—(*Redwood.*)

| SOLUTION. | | | ANHYDROUS AMMONIA. | | | |
|---|---|---|---|---|---|---|
| Weight of Ice. | | Boiling Point. | Volume of Gas, at 32° Fahr., and Atmospheric pressure) in one volume of the Solution. | lbs. in one gallon of the Solution. | Per cent. by Volume. | Per cent. by Weight. |
| Degrees Beaumé. | lbs. per Gallon. | | | | | |
| 34·7 | 7·09 | 26° | 494 | 3·077 | 59·5 | 43·4 |
| 32·8 | 7·17 | 38° | 456 | 2·841 | 54·9 | 39·6 |
| 31·0 | 7·25 | 50° | 419 | 2·610 | 50·7 | 36·0 |
| 29·0 | 7·34 | 62° | 382 | 2·379 | 46·0 | 32·5 |
| 27·2 | 7·42 | 74° | 346 | 2·156 | 41·7 | 29·1 |
| 26·0 | 7·48 | 83° | 320 | 1·993 | 38·5 | 26·6 |
| 25·6 | 7·50 | 86° | 311 | 1·937 | 37·5 | 25·8 |
| 23·7 | 7·59 | 98° | 277 | 1·726 | 33·4 | 22·8 |
| 22·2 | 7·67 | 110° | 244 | 1·520 | 29·4 | 19·7 |

TEMPERATURES TO WHICH AMMONIA GAS IS RAISED BY COMPRESSION.

| Temperature of Suction. | Absolute Condensing Pressure. | ABSOLUTE SUCTION PRESSURE. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20 | 25 | 30 | 35 | 40 | 45 |
| 0° Fahr. | 90 | 199 | 165 | 138 | 116 | 98 | 83 |
| | 100 | 216 | 181 | 153 | 131 | 113 | 97 |
| | 110 | 232 | 196 | 166 | 145 | 126 | 109 |
| | 120 | 245 | 211 | 181 | 158 | 138 | 121 |
| | 130 | 261 | 222 | 193 | 169 | 150 | 132 |
| | 140 | 273 | 235 | 205 | 181 | 161 | 143 |
| | 150 | 285 | 246 | 216 | 191 | 171 | 153 |
| | 160 | 296 | 257 | 226 | 202 | 181 | 163 |

TEMPERATURES TO WHICH AMMONIA GAS IS RAISED BY COMPRESSION.—(*Continued.*)

| Temperature of Suction. | Absolute Condensing Pressure | ABSOLUTE SUCTION PRESSURE. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20 | 25 | 30 | 35 | 40 | 45 |
| 5° Fahr. | 90 | 266 | 172 | 145 | 123 | 104 | 89 |
| | 100 | 223 | 186 | 160 | 138 | 119 | 103 |
| | 110 | 239 | 203 | 174 | 151 | 132 | 115 |
| | 120 | 254 | 218 | 188 | 163 | 145 | 127 |
| | 130 | 268 | 230 | 200 | 176 | 156 | 139 |
| | 140 | 281 | 242 | 212 | 188 | 167 | 150 |
| | 150 | 293 | 254 | 223 | 198 | 178 | 160 |
| | 160 | 305 | 265 | 234 | 209 | 188 | 170 |
| 10° Fahr. | 90 | 213 | 178 | 151 | 129 | 110 | 96 |
| | 100 | 231 | 195 | 167 | 144 | 125 | 109 |
| | 110 | 247 | 210 | 181 | 158 | 139 | 122 |
| | 120 | 261 | 226 | 195 | 171 | 151 | 134 |
| | 130 | 275 | 237 | 207 | 183 | 163 | 145 |
| | 140 | 289 | 250 | 219 | 195 | 174 | 156 |
| | 150 | 301 | 262 | 231 | 205 | 185 | 167 |
| | 160 | 313 | 273 | 241 | 216 | 195 | 176 |
| 15° Fahr. | 90 | 221 | 185 | 158 | 135 | 117 | 101 |
| | 100 | 238 | 202 | 173 | 151 | 131 | 115 |
| | 110 | 254 | 217 | 188 | 164 | 145 | 128 |
| | 120 | 269 | 233 | 202 | 178 | 158 | 140 |
| | 130 | 283 | 245 | 214 | 191 | 170 | 152 |
| | 140 | 297 | 257 | 226 | 202 | 181 | 163 |
| | 150 | 309 | 269 | 238 | 213 | 192 | 173 |
| | 160 | 321 | 281 | 249 | 223 | 202 | 183 |
| 20° Fahr. | 90 | 228 | 192 | 164 | 141 | 123 | 106 |
| | 100 | 245 | 209 | 180 | 157 | 137 | 121 |
| | 110 | 262 | 224 | 195 | 171 | 150 | 134 |
| | 120 | 277 | 240 | 209 | 185 | 164 | 146 |
| | 130 | 291 | 252 | 222 | 197 | 176 | 158 |
| | 140 | 305 | 265 | 234 | 209 | 188 | 169 |
| | 150 | 317 | 277 | 245 | 220 | 198 | 180 |
| | 160 | 329 | 288 | 256 | 230 | 209 | 190 |
| 25° Fahr. | 90 | 235 | 199 | 171 | 148 | 129 | 111 |
| | 100 | 252 | 216 | 187 | 163 | 144 | 127 |
| | 110 | 269 | 230 | 200 | 178 | 155 | 140 |
| | 120 | 284 | 247 | 21[illegible] | 191 | 171 | 153 |
| | 130 | 299 | 259 | 229 | 204 | 183 | 165 |
| | 140 | 313 | 271 | 241 | 216 | 104 | 176 |
| | 150 | 325 | 284 | 253 | 227 | 205 | 187 |
| | 160 | 338 | 296 | 264 | 237 | 216 | 197 |

Temperatures to which Ammonia Gas is raised by Compression.—(*Continued.*)

| Temperature of Suction. | Absolute Condensing Pressure. | Absolute Suction Pressure. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20 | 25 | 30 | 35 | 40 | 45 |
| 30° Fahr. | 90 | 242 | 206 | 177 | 154 | 134 | 118 |
| | 100 | 260 | 223 | 193 | 170 | 150 | 133 |
| | 110 | 277 | 239 | 208 | 184 | 164 | 147 |
| | 120 | 292 | 255 | 223 | 198 | 177 | 159 |
| | 130 | 307 | 267 | 236 | 211 | 190 | 171 |
| | 140 | 321 | 280 | 248 | 223 | 201 | 183 |
| | 150 | 334 | 292 | 260 | 234 | 212 | 193 |
| | 160 | 346 | 304 | 271 | 245 | 223 | 203 |
| 32° Fahr. | 90 | 245 | 209 | 179 | 157 | 137 | 121 |
| | 100 | 263 | 225 | 196 | 173 | 153 | 135 |
| | 110 | 280 | 241 | 211 | 187 | 167 | 149 |
| | 120 | 295 | 256 | 226 | 201 | 180 | 162 |
| | 130 | 310 | 270 | 239 | 213 | 192 | 174 |
| | 140 | 324 | 283 | 251 | 226 | 204 | 185 |
| | 150 | 337 | 295 | 263 | 237 | 215 | 196 |
| | 160 | 350 | 307 | 274 | 248 | 226 | 206 |
| 35° Fahr. | 90 | 249 | 213 | 182 | 160 | 141 | 124 |
| | 100 | 268 | 229 | 200 | 176 | 156 | 139 |
| | 110 | 286 | 246 | 215 | 191 | 170 | 153 |
| | 120 | 300 | 260 | 230 | 205 | 184 | 166 |
| | 130 | 315 | 274 | 243 | 217 | 196 | 178 |
| | 140 | 329 | 288 | 255 | 230 | 208 | 189 |
| | 150 | 341 | 300 | 268 | 241 | 219 | 200 |
| | 160 | 354 | 312 | 279 | 252 | 230 | 210 |

## The Analyser.

The analyser is placed in upper part of still or generator of absorption machine, and serves as a dehydrator, also increasing temperature of rich liquor from 150° to 170°, at which it arrives, to about 200°.

The device consists essentially of superimposed shelves down which the rich ammonia liquor is delivered and over which it trickles, whilst the heated vapour from generator passes over them in an upward direction. In this manner

the hot vapour is caused to come in contact with a large surface of the rich ammonia liquor, and becomes both enriched in ammonia and deprived of a large percentage of water by the time it reaches the top of the analyser.

PROPERTIES OF SATURATED AMMONIA GAS.—(*Yaryan.*)

| Temperature Fahr. | Pressure from vacuum in lbs. per sq. in. | Heat of vaporization. | Volume of vapour per lb. cubic ft. | Volume of liquid per lb. cubic ft. | Gauge pressure per sq. in. |
|---|---|---|---|---|---|
| −40 | 10·69 | 579·67 | 24·38 | 0·0234 | 0· |
| −35 | 12·31 | 576·69 | 21·21 | 0·0236 | 0· |
| −30 | 14·13 | 573·69 | 18·67 | 0·0237 | 0· |
| −25 | 16·17 | 570·68 | 16·42 | 0·0238 | 1·47 |
| −20 | 18·45 | 567·67 | 14·48 | 0·0240 | 3·75 |
| −15 | 20·99 | 564·64 | 12·81 | 0·0242 | 6·29 |
| −10 | 23·77 | 561·61 | 11·36 | 0·0243 | 9·07 |
| − 5 | 27·57 | 558·56 | 9·89 | 0·0244 | 12·87 |
| 0 | 30·37 | 555·5 | 9·14 | 0·0246 | 15·67 |
| + 5 | 34·17 | 552·43 | 8·04 | 0·0247 | 19·47 |
| +10 | 38·55 | 549·35 | 7·20 | 0·0249 | 23·85 |
| +15 | 42·93 | 546·26 | 6·46 | 0·0250 | 28·23 |
| +20 | 47·95 | 543·15 | 5·82 | 0·0252 | 33·25 |
| +25 | 53·43 | 540·03 | 5·24 | 0·0253 | 38·73 |
| +30 | 59·41 | 536·92 | 4·73 | 0·0254 | 44·71 |
| +35 | 65·93 | 533·78 | 4·28 | 0·0256 | 51·23 |
| +40 | 73·00 | 530·63 | 3·88 | 0·0257 | 58·30 |
| +45 | 80·66 | 527·47 | 3·53 | 0·0260 | 65·96 |
| +50 | 88·96 | 524·30 | 3·21 | 0·02601 | 74·26 |
| +55 | 97·63 | 521·12 | 2·93 | 0·02603 | 82·93 |
| +60 | 107·60 | 517·93 | 2·67 | 0·0265 | 92·90 |
| +65 | 118·03 | 515·33 | 2·45 | 0·0266 | 103·33 |
| +70 | 129·21 | 511·52 | 2·24 | 0·0268 | 114·51 |
| +75 | 141·25 | 508·29 | 2·05 | 0·0270 | 126·55 |
| +80 | 154·11 | 504·66 | 1·89 | 0·0272 | 139·41 |
| +85 | 167·86 | 501·81 | 1·74 | 0·0273 | 153·16 |
| +90 | 182·8 | 498·11 | 1·61 | 0·274 | 168·10 |
| +95 | 198·37 | 495·29 | 1·48 | 0·277 | 183·67 |
| +100 | 215·14 | 491·50 | 1·36 | 0·279 | 200·44 |

## Volume of One Pound of Ammonia Gas at Various Pressures and Temperatures.

| lbs. per Square Inch Absolute Pressure. | Temperature in Degrees, Fahrenheit. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| | Volume in Cubic Feet of One lb. of Ammonia Gas. | | | | | | | |
| 15 | 19·823 | 20·036 | 20·263 | 20·490 | 20·703 | 20·930 | 21·156 | 21·370 |
| 15½ | 19·175 | 19·382 | 19·601 | 19·821 | 20·027 | 20·246 | 20·466 | 20·672 |
| 16 | 18·569 | 18·769 | 18·982 | 19·194 | 19·410 | 19·607 | 19·819 | 20·019 |
| 16½ | 17·999 | 18·193 | 18·399 | 18·605 | 18·799 | 19·005 | 19·211 | 19·405 |
| 17 | 17·463 | 17·651 | 17·865 | 18·051 | 18·239 | 18·439 | 18·639 | 18·828 |
| 17½ | 16·958 | 17·141 | 17·355 | 17·529 | 17·711 | 17·906 | 18·101 | 18·283 |
| 18 | 16·481 | 16·658 | 16·847 | 17·036 | 17·215 | 17·403 | 17·591 | 17·769 |
| 18½ | 16·029 | 16·202 | 16·386 | 16·570 | 16·743 | 16·926 | 17·110 | 17·283 |
| 19 | 15·602 | 15·770 | 15·949 | 16·128 | 16·296 | 16·475 | 16·654 | 16·824 |
| 19½ | 15·196 | 15·360 | 15·534 | 15·709 | 15·873 | 16·047 | 16·222 | 16·386 |
| 20 | 14·811 | 14·971 | 15·141 | 15·311 | 15·471 | 15·642 | 15·811 | 15·971 |
| 20½ | 14·444 | 14·600 | 14·771 | 14·932 | 15·088 | 15·254 | 15·420 | 15·576 |
| 21 | 14·096 | 14·249 | 14·410 | 14·572 | 14·725 | 14·887 | 15·049 | 15·201 |
| 21½ | 13·763 | 13·912 | 14·070 | 14·228 | 14·377 | 14·535 | 14·693 | 14·842 |
| 22 | 13·447 | 13·594 | 13·747 | 13·901 | 14·047 | 14·201 | 14·356 | 14·501 |
| 22½ | 13·143 | 13·285 | 13·436 | 13·588 | 13·730 | 13·881 | 14·032 | 14·174 |
| 23 | 12·851 | 12·993 | 13·141 | 13·288 | 13·428 | 13·576 | 13·723 | 13·863 |
| 23½ | 12·576 | 12·712 | 12·857 | 13·001 | 13·137 | 13·286 | 13·427 | 13·563 |
| 24 | 12·310 | 12·444 | 12·585 | 12·727 | 12·861 | 13·004 | 13·144 | 13·277 |
| 24½ | 12·055 | 12·186 | 12·325 | 12·464 | 12·594 | 12·733 | 12·872 | 13·002 |
| 25 | 11·811 | 11·939 | 12·075 | 12·211 | 12·339 | 12·473 | 12·611 | 12·739 |

VOLUME OF ONE POUND OF AMMONIA GAS AT VARIOUS PRESSURES AND TEMPERATURES.—(Continued.)

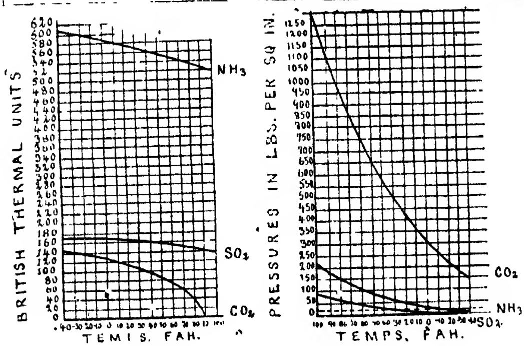
| lbs. per Square Inch Absolute Pressure. | TEMPERATURE IN DEGREES, FAHRENHEIT. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| | Volume in Cubic Feet of One lb. of Ammonia Gas. | | | | | | | |
| 25½ | 11·576 | 11·702 | 11·835 | 11·964 | 12·094 | 12·227 | 12·360 | 12·486 |
| 26 | 11·350 | 11·473 | 11·604 | 11·735 | 11·857 | 11·988 | 12·119 | 12·242 |
| 26½ | 11·133 | 11·254 | 11·382 | 11·510 | 11·631 | 11·755 | 11·888 | 12·008 |
| 27 | 10·923 | 11·042 | 11·167 | 11·294 | 11·412 | 11·538 | 11·664 | 11·783 |
| 27½ | .0·722 | 10·838 | 10·962 | 11·085 | 11·202 | 11·325 | 11·449 | 11·565 |
| 28 | 10·527 | 10·642 | 10·763 | 10·885 | 10·999 | 11·120 | 11·242 | 11·F363 |
| 28½ | 10·340 | 10·452 | 10·572 | 10·691 | 10·803 | 10·922 | 11·042 | 11·154 |
| 29 | 10·159 | 10·369 | 10·386 | 10·504 | 10·611 | 10·731 | 10·848 | 10·959 |
| 29½ | 9·984 | 10·093 | 10·208 | 10·323 | 10·432 | 10·547 | 10·662 | 10·770 |
| 30 | 9·813 | 10·921 | 10·035 | 10·148 | 10·255 | 10·368 | 10·482 | 10·588 |
| 30½ | 9·651 | 9·756 | 9·868 | 9·979 | 10·084 | 10·196 | 10·307 | 10·412 |
| 31 | 9·493 | 9·597 | 9·706 | 9·816 | 9·919 | 10·029 | 10·139 | 10·242 |
| 31½ | 9·340 | 9·442 | 9·550 | 9·558 | 9·759 | 9·867 | 9·975 | 10·077 |
| 32 | 9·192 | 9·292 | 9·399 | 9·505 | 9·605 | 9·711 | 9·817 | 9·9!7 |
| 32½ | 9·048 | 9·147 | 9·251 | 9·356 | 9·454 | 9·559 | 9·664 | 9·762 |
| 33 | 8·909 | 9·006 | 9·109 | 9·212 | 9·309 | 9·412 | 9·515 | 9·612 |
| 33½ | 8·774 | 8·870 | 8·971 | 9·072 | 9·168 | 9·269 | 9·371 | 9·467 |
| 34 | 8·644 | 8·738 | 8·838 | 8·938 | 9·032 | 9·132 | 9·232 | 9·326 |
| 34½ | 8·516 | 8·608 | 8·707 | 8·806 | 8·899 | 8·997 | 9·095 | 9·188 |
| 35 | 8·391 | 8·483 | 8·580 | 8·677 | 8·769 | 8·866 | 8·962 | 9·055 |

VOLUME OF ONE POUND OF AMMONIA GAS AT VARIOUS PRESSURES AND TEMPERATURES.—(*Continued.*)

| lbs. per Square Inch Absolute Pressure. | TEMPERATURE IN DEGREES, FAHRENHEIT. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| | Volume in Cubic Feet of One lb. of Ammonia Gas. | | | | | | | |
| 35½ | 8·271 | 8·361 | 8·457 | 8·553 | 8·643 | 8·739 | 8·834 | 8·925 |
| 36 | 8·155 | 8·244 | 8·338 | 8·433 | 8·521 | 8·616 | 8·711 | 8·799 |
| 36½ | 8·041 | 8·129 | 8·222 | 8·315 | 8·403 | 8·496 | 8·589 | 8·679 |
| 37 | 7·931 | 8·017 | 8·109 | 8·201 | 8·288 | 8·379 | 8·471 | 8·558 |
| 37½ | 7·823 | 7·908 | 7·999 | 8·089 | 8·172 | 8·265 | 8·356 | 8·441 |
| 38 | 7·719 | 7·803 | 7·892 | 7·982 | 8·066 | 8·155 | 8·245 | 8·329 |
| 38½ | 7·616 | 7·699 | 7·788 | 7·876 | 7·959 | 8·047 | 8·136 | 8·219 |
| 39 | 7·516 | 7·599 | 7·686 | 7·774 | 7·856 | 7·943 | 8·030 | 8·113 |
| 39½ | 7·421 | 7·501 | 7·587 | 7·673 | 7·754 | 7·840 | 7·926 | 8·007 |
| 40 | 7·326 | 7·406 | 7·491 | 7·576 | 7·656 | 7·741 | 7·826 | 7·906 |
| 40½ | 7·234 | 7·313 | 7·397 | 7·480 | 7·560 | 7·643 | 7·727 | 7·806 |
| 41 | 7·144 | 7·222 | 7·305 | 7·388 | 7·466 | 7·549 | 7·632 | 7·710 |
| 41½ | 7·056 | 7·134 | 7·215 | 7·297 | 7·374 | 7·456 | 7·538 | 7·615 |
| 42 | 6·971 | 7·047 | 7·129 | 7·209 | 7·286 | 7·366 | 7·448 | 7·524 |
| 42½ | 6·888 | 6·963 | 7·043 | 7·123 | 7·199 | 7·279 | 7·358 | 7·434 |
| 43 | 6·806 | 6·881 | 6·959 | 7·039 | 7·113 | 7·192 | 7·271 | 7·346 |
| 43½ | 6·727 | 6·800 | 6·879 | 6·957 | 7·030 | 7·108 | 7·186 | 7·260 |
| 44 | 6·649 | 6·722 | 6·799 | 6·876 | 6·949 | 7·026 | 7·103 | 7·176 |
| 44½ | 6·573 | 6·645 | 6·721 | 6·798 | 6·870 | 6·946 | 7·022 | 7·094 |
| 45 | 6·498 | 6·569 | 6·652 | 6·721 | 6·792 | 6·867 | 6·943 | 7·014 |

## VOLUME OF AMMONIA GAS AT HIGH TEMPERATURES.
—(*Redwood.*)

| GAUGE PRESSURE | TEMPERATURE OF GAS. | | | | | |
|---|---|---|---|---|---|---|
| | 60° | 71° | 80° | 81° | 90° | 95° |
| | VOLUME OF 1 LB. OF GAS IN CUBIC FEET. | | | | | |
| 80 | 3·470 | | | | | |
| 85 | 3·292 | | | | | |
| 90 | 3·131 | | | | | |
| 95 | | 3·035 | | | | |
| 100 | | 2·900 | | | | |
| 105 | | 2·785 | | | | |
| 110 | | | 2·695 | | | |
| 115 | | | 2·590 | | | |
| 120 | | | 2·490 | | | |
| 125 | | | | 2·418 | | |
| 130 | | | | 2·333 | | |
| 135 | | | | 2·252 | | |
| 140 | | | | | 2·204 | |
| 145 | | | | | 2·134 | |
| 150 | | | | | | 2·088 |
| 155 | | | | | | 2·037 |




FIGS. 19 and 20.—Diagrams showing Curves of Latent Heat of Vaporisation (1 lb. each Saturated Vapour), and Curves of Absolute Pressure for Saturated Vapours of $NH_3$, $SO_2$, and $CO_2$, from $-40°$ to $+100°$ Fahr. 1 lb. each Saturated Vapour.—(*Murray, Inst. Engrs. and Shipbuilders, Scotland*, 1897.)

## SATURATED VAPOUR OF ANHYDROUS AMMONIA ($NH_3$).

(*Dieterici and Volsa.* "*Vapour Compression Refrigerating Machines,*" *by J. Wemyss Anderson, M.Eng.,* "*Proceedings, Inst. Mech. Engrs.,* 1914.")

| Temperature $t$ Fahr. | Pressure. Lb. per sq. in. $p$. | Specific volume of vapour $v$. | Sensible heat of liquid S. | Latent heat. Total L. | Latent heat. External $L_e$. | Latent heat. Internal $L_i$. | Entropy of the liquid $\phi_w$. | $\frac{L}{\tau}$ $\phi_r$. | Temperature $t$ Fahr. |
|---|---|---|---|---|---|---|---|---|---|
| −22 | 16·93 | 15·81 | −58·88 | 590·3 | 49·5 | 540·8 | −0·1265 | 1·350 | −22 |
| −13 | 21·47 | 12·66 | −49·34 | 584·0 | 50·2 | 533·8 | −0·1048 | 1·309 | −13 |
| −4 | 26·98 | 10·21 | −39·70 | 576·9 | 50·9 | 527·0 | −0·0835 | 1·269 | −4 |
| +5 | 33·61 | 8·30 | −29·88 | 570·4 | 51·5 | 548·9 | −0·0622 | 1·230 | +5 |
| 14 | 41·51 | 6·81 | −20·06 | 563·5 | 52·1 | 511·4 | −0·0414 | 1·190 | 14 |
| 23 | 50·82 | 5·63 | −10·02 | 555·9 | 52·5 | 503·4 | −0·0206 | 1·152 | 23 |
| 32 | 61·73 | 4·66 | 0 | 547·9 | 53·1 | 494·8 | 0 | 1·116 | 32 |
| 41 | 74·44 | 3·91 | +10·15 | 539·7 | 53·5 | 486·2 | 0·0205 | 1·079 | 41 |
| 50 | 89·05 | 3·29 | 20·45 | 531·4 | 53·8 | 477·6 | 0·0405 | 1·042 | 50 |
| 59 | 105·80 | 2·79 | 30·81 | 522·2 | 54·0 | 468·2 | 0·0607 | 1·006 | 59 |
| 68 | 124·85 | 2·37 | 41·34 | 512·6 | 54·2 | 458·4 | 0·0805 | 0·971 | 68 |
| 77 | 146·26 | 2·04 | 51·89 | 502·7 | 54·3 | 448·4 | 0·1003 | 0·936 | 77 |
| 86 | 170·53 | 1·75 | 62·55 | 492·4 | 54·2 | 438·2 | 0·1207 | 0·901 | 86 |
| 95 | 197·47 | 1·51 | 73·42 | 481·5 | 54·1 | 427·4 | 0·1392 | 0·869 | 95 |
| 104 | 227·36 | 1·30 | 83·19 | 471·2 | 53·7 | 417·5 | 0·1583 | 0·834 | 104 |

L = latent heat. $p$ = pressure lb. sq. in. absolute. S = sensible heat. $t$ = temperature degrees F. $v$ = specific volume of vapour. $\tau$ = absolute temperature degrees F. $i$ = enthalpy. $\phi$ = entropy.

## SATURATED VAPOUR OF CARBONIC ANHYDRIDE ($CO_2$).

(*Amagat and Mollier.* "*Vapour Compression Refrigerating Machines,*" *by J. Wemyss Anderson, M.Eng.,* "*Proceedings, Inst. Mech. Engrs.,* 1912.")

| Temperature $t$ Fahr. | Pressure lb. per sq. in. $p$. | Specific Volume. | | Sensible heat of liquid S. | Latent heat. | | | Entropy of Liquid $\phi_w$. | $\frac{L}{\tau}$ $\phi_t$ | Temperature $t$ Fahr. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Liquid $s$. | Vapour $v$. | | Total L. | External $L_e$. | Internal $L_i$. | | | |
| −22 | 213·0 | 0·0155 | 0·4323 | −25·72 | 126·13 | 16·40 | 109·73 | −0·0533 | 0·2863 | −22 |
| −13 | 248·5 | 0·0157 | 0·3674 | −21·87 | 122·67 | 16·18 | 106·49 | −0·0448 | 0·2748 | −13 |
| − 4 | 288·3 | 0·0160 | 0·3132 | −17·87 | 118·86 | 15·88 | 102·98 | −0·0363 | 0·2611 | − 4 |
| + 5 | 333·7 | 0·0164 | 0·2674 | −13·73 | 114·71 | 15·53 | 99·18 | −0·0276 | 0·2470 | + 5 |
| 14 | 384·8 | 0·0167 | 0·2286 | − 9·38 | 110·12 | 15·08 | 95·04 | −0·0186 | 0·2326 | 14 |
| 23 | 440·2 | 0·0172 | 0·1952 | − 4·82 | 105·04 | 14·55 | 90·49 | −0·0095 | 0·2170 | 23 |
| 32 | 502·7 | 0·0176 | 0·1669 | 0·00 | 99·34 | 13·89 | 85·45 | 0·0000 | 0·2021 | 32 |
| 41 | 573·3 | 0·0182 | 0·1422 | + 5·17 | 92·91 | 13·15 | 79·76 | +0·0099 | 0·1857 | 41 |
| 50 | 648·9 | 0·0188 | 0·1205 | 10·76 | 85·54 | 12·23 | 73·31 | 0·0205 | 0·1679 | 50 |
| 59 | 732·7 | 0·0197 | 0·1010 | 17·01 | 76·84 | 11·09 | 65·75 | 0·0321 | 0·1482 | 59 |
| 68 | 825·0 | 0·0210 | 0·0840 | 24·21 | 66·15 | 9·61 | 56·54 | 0·0452 | 0·1255 | 68 |
| 77 | 928·7 | 0·0228 | 0·0672 | 33·19 | 51·91 | 7·23 | 44·28 | 0·0613 | 0·0968 | 77 |
| 86 | 1038·0 | 0·0268 | 0·0474 | 47·50 | 26·88 | 3·98 | 22·90 | 0·0868 | 0·0493 | 86 |
| 87·8 | 1060·7 | 0·0298 | 0·0412 | 53·77 | 15·04 | 2·22 | 12·89 | 0·0981 | 0·0275 | 87·8 |
| 88·4 | 1069·3 | 0·0346 | 0·0346 | 61·43 | 0·00 | 0·00 | 0·00 | 0·1120 | 0·0000 | 88·4 |

## Saturated Vapour of Sulphurous Anhydride ($SO_2$).

(*Cailletet and Mathias.* "*Vapour Compression Refrigerating Machines,*" *by J. Wemyss Anderson, M.Eng.,* "*Proceedings, Inst. Mech. Engrs.,* 1914.")

| Temperature $t$ Fahr. | Pressure lb. per sq. in. $p$. | Specific Volume of Vapour $v$. | Sensible heat S. | Latent heat. Total L. | External $L_e$. | Internal $L_i$. | Entropy of Liquid $\phi_w$. | $\frac{L}{\tau}$ $\phi_r$. | Temperature $t$ Fahr. |
|---|---|---|---|---|---|---|---|---|---|
| −22 | 5·54 | 13·177 | −16·29 | 175·99 | 13·50 | 162·49 | −0·0351 | 0·4023 | −22 |
| −13 | 7·24 | 10·307 | −13·72 | 174·42 | 13·81 | 160·61 | −0·0293 | 0·3907 | −13 |
| −4 | 9·23 | 8·223 | −11·07 | 172·66 | 14·04 | 158·62 | −0·0234 | 0·3791 | −4 |
| +5 | 11·79 | 6·668 | −8·39 | 170·68 | 14·26 | 156·42 | −0·0176 | 0·3675 | +5 |
| 14 | 14·77 | 5·290 | −5·65 | 168·48 | 14·45 | 154·03 | −0·0117 | 0·3559 | 14 |
| 23 | 18·32 | 4·328 | −2·84 | 166·08 | 14·62 | 151·46 | −0·0059 | 0·3443 | 23 |
| 32 | 22·44 | 3·574 | 0·00 | 163·48 | 14·76 | 148·72 | 0·0000 | 0·3327 | 32 |
| 41 | 27·40 | 2·950 | +2·90 | 160·65 | 14·87 | 145·78 | +0·0059 | 0·3210 | 41 |
| 50 | 33·23 | 2·437 | 5·85 | 157·61 | 14·90 | 142·71 | 0·0117 | 0·3094 | 50 |
| 59 | 39·90 | 2·036 | 8·86 | 155·36 | 14·94 | 140·42 | 0·0176 | 0·2978 | 59 |
| 68 | 47·57 | 1·715 | 11·92 | 150·93 | 14·94 | 135·99 | 0·0234 | 0·2862 | 68 |
| 77 | 56·23 | 1·443 | 15·03 | 147·28 | 14·90 | 132·38 | 0·0293 | 0·2740 | 77 |
| 86 | 66·31 | 1·218 | 18·20 | 143·80 | 14·81 | 128·59 | 0·0351 | 0·2629 | 86 |
| 95 | 77·53 | 1·042 | 21·42 | 139·32 | 14·69 | 124·63 | 0·0410 | 0·2513 | 95 |
| 104 | 90·17 | 0·882 | 24·68 | 135·05 | 14·55 | 120·50 | 0·0468 | 0·2397 | 104 |

## SULPHUROUS ANHYDRIDE, $SO_2$.

Regnault established the relationship between the temperature and pressure, and furnished the data for $p$ and $t$ given in the table. The values of $v$ and $s$ have been given by the experiments of Cailletet and Mathias, and those of $c$ by Mathias. The value of $c$ enables $s$ to be calculated, while the values of $v$ and $s$ enable L to be determined.

Knowing S and L, H, $\phi_w$ and $\phi_s$ can be found, and in this way the figures given in the following table have been obtained.

### PROPERTIES OF $SO_2$.

| | |
|---|---|
| Critical temperature .. .. | 312·8° Fahr. |
| Critical pressure .. .. . | 1159·6 lbs. per sq. in. |
| Specific volume of liquid .. | 0·0112 cubic foot (mean). |
| Specific heat of liquid .. .. | 0·40 (mean). |
| $K_p$ .. .. .. .. .. | 0·154. |
| $K_v$ .. .. .. .. .. | 0·123. |
| $\gamma$ .. .. .. .. .. | 1·25. |

### PROPERTIES OF $NH_3$.

| | |
|---|---|
| Critical temperature .. .. | 206·0° Fahr. |
| Critical pressure .. . .. | 1624·0 lbs. per sq. in. |
| Specific volume of liquid .. | 0·0256 cubic foot (mean). |
| Specific heat of liquid .. .. | 1·02. |
| $K_p$ .. .. .. .. .. | 0·508. |
| $K_v$ .. .. .. .. .. | 0·393. |
| $\gamma$ .. .. .. .. .. | 1·29. |

### PROPERTIES OF $CO_2$.

| | |
|---|---|
| Critical temperature .. .. | 88·43° Fahr. |
| Critical pressure .. .. .. | 1071 lbs. per sq. in. |
| Specific heat of liquid .. .. | 0·98 (mean). |
| $K^p$ .. .. .. .. .. | 0·217. |
| $K^v$ .. .. .. .. .. | 0·171. |
| $\gamma$ .. .. .. .. .. | 1·26. |

(*J. Wemyss Anderson, M.Eng.*, "*Proc. Inst. M.E.*, 1912.")

WOOD'S TABLE OF SATURATED AMMONIA.
*(Re-calculated by George Davidson, M.E.)*

| Temperature. Degrees F. $t$. | Temperature. Absolute. $T$. | Pressure Absolute. Lbs. per sq. foot. $P$. | Pressure Absolute. Lbs. per sq. inch. $p$. | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| −40 | 420·66 | 1539·90 | 10·69 | −4·01 | 579·67 | 24·388 | 0·02348 | 0·0410 | 42·589 | −40 |
| 39 | 1 | 1584·43 | 11·00 | −3·70 | 579·07 | 23·735 | 0·02351 | 0·0421 | 42·535 | 39 |
| 38 | 2 | 1630·03 | 11·32 | −3·38 | 578·42 | 23·102 | 0·02354 | 0·0433 | 42·483 | 38 |
| 37 | 3 | 1676·71 | 11·64 | −3·06 | 577·88 | 22·488 | 0·02357 | 0·0444 | 42·427 | 37 |
| 36 | 4 | 1724·51 | 11·98 | −2·72 | 577·27 | 21·895 | 0·02359 | 0·0457 | 42·391 | 36 |
| −35 | 425·66 | 1773·43 | 12·31 | −2·39 | 576·68 | 21·321 | 0·02362 | 0·0469 | 42·337 | −35 |
| 34 | 6 | 1823·50 | 12·66 | −2·04 | 576·08 | 20·763 | 0·02364 | 0·0482 | 42·301 | 34 |
| 33 | 7 | 1874·73 | 13·02 | −1·68 | 575·48 | 20·221 | 0·02366 | 0·0495 | 42·265 | 33 |
| 32 | 8 | 1927·17 | 13·38 | −1·32 | 574·89 | 19·708 | 0·02368 | 0·0507 | 42·213 | 32 |
| 31 | 9 | 1980·78 | 13·75 | −0·95 | 574·39 | 19·204 | 0·02371 | 0·0521 | 42·176 | 31 |
| −30 | 430·66 | 2035·69 | 14·13 | −0·57 | 573·69 | 18·693 | 0·02374 | 0·0535 | 42·123 | −30 |
| 29 | 1 | 2091·83 | 14·53 | −0·17 | 573·08 | 18·225 | 0·02378 | 0·0549 | 42·052 | 29 |
| 28 | 2 | 2149·23 | 14·92 | +0·22 | 572·48 | 17·759 | 0·02381 | 0·0563 | 42·000 | 28 |
| 27 | 3 | 2207·94 | 15·33 | +0·63 | 571·89 | 17·307 | 0·02384 | 0·0577 | 41·946 | 27 |
| 26 | 4 | 2267·97 | 15·75 | +1·05 | 571·28 | 16·869 | 0·02387 | 0·0593 | 41·893 | 26 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| −25 | 435·66 | 2329·34 | 16·17 | +1·47 | 570·68 | 16·446 | 0·02389 | 0·0608 | 41·858 | −25 |
| 24 | 6 | 2392·09 | 16·61 | 1·91 | 570·08 | 16·034 | 0·02392 | 0·0624 | 41·806 | 24 |
| 23 | 7 | 2456·23 | 17·05 | 2·35 | 569·48 | 15·633 | 0·02395 | 0·0640 | 41·754 | 32 |
| 22 | 8 | 2520·45 | 17·50 | 2·8 | 568·88 | 15·252 | 0·02398 | 0·0656 | 41·701 | 22 |
| 21 | 9 | 2588·77 | 17·97 | 3·27 | 568·27 | 14·875 | 0·02401 | 0·0672 | 41·649 | 21 |
| −20 | 440·66 | 2657·23 | 18·45 | +3·75 | 567·67 | 14·507 | 0·02403 | 0·0689 | 41·615 | −20 |
| 19 | 1 | 2727·17 | 18·94 | 4·24 | 567·06 | 14·153 | 0·02406 | 0·0706 | 41·563 | 19 |
| 18 | 2 | 2798·62 | 19·43 | 4·73 | 566·43 | 13·807 | 0·02409 | 0·0725 | 41·511 | 18 |
| 17 | 3 | 2871·61 | 19·94 | 5·24 | 565·85 | 13·475 | 0·02411 | 0·0742 | 41·410 | 17 |
| 16 | 4 | 2946·17 | 20·46 | 5·76 | 565·25 | 13·150 | 0·02414 | 0·0760 | 41·425 | 16 |
| −15 | 445·66 | 3022·31 | 20·99 | +6·29 | 564·64 | 12·834 | 0·02417 | 0·0779 | 41·374 | −15 |
| 14 | 6 | 3100·07 | 21·53 | 6·83 | 564·04 | 12·527 | 0·02420 | 0·0798 | 41·322 | 14 |
| 13 | 7 | 3179·45 | 22·08 | 7·38 | 563·43 | 12·230 | 0·02423 | 0·0818 | 41·271 | 13 |
| 12 | 8 | 3260·52 | 22·64 | 7·94 | 562·82 | 11·939 | 0·02425 | 0·0838 | 41·237 | 12 |
| 11 | 9 | 3343·29 | 23·22 | 8·52 | 562·21 | 11·659 | 0·02428 | 0·0858 | 41·186 | 11 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| −10 | 450·66 | 3427·75 | 23·80 | + 9·10 | 561·61 | 11·385 | 0·02431 | 0·0878 | 41·135 | −10 |
| 9 | 1 | 3513·97 | 24·40 | 9·70 | 560·99 | 11·117 | 0·02434 | 0·0899 | 41·084 | 9 |
| 8 | 2 | 3601·97 | 25·01 | 10·31 | 560·39 | 10·860 | 0·02437 | 0·0921 | 41·034 | 8 |
| 7 | 3 | 3691·75 | 25·64 | 10·94 | 559·78 | 10·604 | 0·02439 | 0·0943 | 41·000 | 7 |
| 6 | 4 | 3783·37 | 26·27 | 11·57 | 559·17 | 10·362 | 0·02442 | 0·0965 | 40·950 | 6 |
| −5 | 455·66 | 3876·85 | 26·92 | + 12·22 | 558·56 | 10·125 | 0·02445 | 0·0988 | 40·900 | −5 |
| 4 | 6 | 3972·62 | 27·59 | 12·89 | 557·94 | 9·894 | 0·02448 | 0·1011 | 40·845 | 4 |
| 3 | 7 | 4069·48 | 28·26 | 13·56 | 557·33 | 9·669 | 0·02451 | 0·1034 | 40·799 | 3 |
| 2 | 8 | 4168·70 | 28·95 | 14·25 | 556·73 | 9·449 | 0·02454 | 0·1058 | 40·749 | 2 |
| 1 | 9 | 4269·90 | 29·65 | 14·95 | 556·11 | 9·234 | 0·02457 | 0·1083 | 40·700 | 1 |
| +0 | 460·66 | 4373·10 | 30·37 | + 15·67 | 555·50 | 9·028 | 0·02461 | 0·1107 | 40·650 | +0 |
| 1 | 1 | 4478·32 | 31·10 | 16·40 | 554·88 | 8·825 | 0·02463 | 0·1133 | 40·601 | 1 |
| 2 | 2 | 4585·60 | 31·84 | 17·14 | 554·27 | 8·630 | 0·02466 | 0·1159 | 40·551 | 2 |
| 3 | 3 | 4694·96 | 32·60 | 17·90 | 553·65 | 8·436 | 0·02469 | 0·1186 | 40·502 | 3 |
| 4 | 4 | 4806·46 | 33·38 | 18·68 | 553·04 | 8·250 | 0·02472 | 0·1212 | 40·453 | 4 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. Degrees F. | Temperature. Absolute. $T$. | Pressure Absolute. Lbs. per sq. foot. $P$. | Pressure Absolute. Lbs. per sq. inch. $p$. | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| +5 | 465·66 | 4920·11 | 34·16 | +19·46 | 552·43 | 8·070 | 0·02475 | 0·1240 | 40·404 | +5 |
| 6 | 6 | 5035·95 | 34·97 | 20·27 | 551·81 | 7·892 | 0·02478 | 0·1267 | 40·355 | 6 |
| 7 | 7 | 5153·99 | 35·79 | 21·09 | 551·19 | 7·717 | 0·02480 | 0·1296 | 40·322 | 7 |
| 8 | 8 | 5274·28 | 36·63 | 21·93 | 550·58 | 7·553 | 0·02483 | 0·1324 | 40·274 | 8 |
| 9 | 9 | 5396·83 | 37·48 | 22·78 | 549·56 | 7·388 | 0·02486 | 0·1353 | 40·225 | 9 |
| +10 | 470·66 | 5521·71 | 38·34 | +23·64 | 549·35 | 7·229 | 0·02490 | 0·1383 | 40·160 | +10 |
| 11 | 1 | 5649·48 | 39·23 | 24·53 | 548·73 | 7·075 | 0·02493 | 0·1413 | 40·112 | 11 |
| 12 | 2 | 5778·50 | 40·13 | 25·43 | 548·11 | 6·924 | 0·02496 | 0·1444 | 40·064 | 12 |
| 13 | 3 | 5910·52 | 41·04 | 26·34 | 547·49 | 6·786 | 0·02499 | 0·1474 | 40·016 | 13 |
| 14 | 4 | 6044·96 | 41·98 | 27·28 | 546·88 | 6·632 | 0·02502 | 0·1507 | 39·968 | 14 |
| +15 | 475·66 | 6182·00 | 42·94 | +28·24 | 546·26 | 6·491 | 0·02505 | 0·1541 | 39·920 | +15 |
| 16 | 6 | 6321·24 | 43·90 | 29·20 | 545·63 | 6·355 | 0·02508 | 0·1573 | 39·872 | 16 |
| 17 | 7 | 6463·24 | 44·88 | 30·18 | 545·01 | 6·222 | 0·02511 | 0·1607 | 39·872 | 17 |
| 18 | 8 | 6607·77 | 45·89 | 31·19 | 544·39 | 6·093 | 0·02514 | 0·1641 | 39·777 | 18 |
| 19 | 9 | 6754·90 | 46·91 | 32·21 | 543·74 | 5·966 | 0·02517 | 0·1676 | 39·729 | 19 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. Degrees F. $t$. | Temperature. Absolute. $T$. | Pressure Absolute. Lbs. per sq. foot. $P$. | Pressure Absolute. Lbs. per sq. inch. $p$. | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| + 20 | 480·66 | 6904·68 | 47·95 | + 33·25 | 543·15 | 5·843 | 0·02520 | 0·1711 | 39·682 | + 20 |
| 21 | 1 | 7057·15 | 49·01 | 34·31 | 542·53 | 5·722 | 0·02523 | 0·1748 | 39·635 | 21 |
| 22 | 2 | 7211·33 | 50·09 | 35·39 | 541·90 | 5·605 | 0·02527 | 0·1784 | 39·572 | 22 |
| 23 | 3 | 7370·27 | 51·18 | 36·48 | 541·28 | 5·488 | 0·02529 | 0·1822 | 39·541 | 23 |
| 24 | 4 | 7530·96 | 52·30 | 37·60 | 540·66 | 5·378 | 0·02533 | 0·1860 | 39·479 | 24 |
| + 25 | 485·66 | 7694·52 | 53·43 | + 38·73 | 540·03 | 5·270 | 0·02536 | 0·1897 | 39·432 | + 25 |
| 26 | 6 | 7860·89 | 54·59 | 39·89 | 539·41 | 5·163 | 0·02539 | 0·1937 | 39·386 | 26 |
| 27 | 7 | 8030·16 | 55·76 | 41·06 | 538·78 | 5·058 | 0·02542 | 0·1977 | 39·339 | 27 |
| 28 | 8 | 8202·38 | 56·96 | 42·26 | 538·16 | 4·960 | 0·02545 | 0·2016 | 39·292 | 28 |
| 29 | 9 | 8377·56 | 58·17 | 43·47 | 537·53 | 4·858 | 0·02548 | 0·2059 | 39·246 | 29 |
| + 30 | 490·66 | 8555·74 | 59·42 | + 44·72 | 536·91 | 4·763 | 0·02551 | 0·2099 | 39·200 | + 30 |
| 31 | 1 | 8736·96 | 60·67 | 45·97 | 536·28 | 4·668 | 0·02554 | 0·2142 | 39·115 | 31 |
| 32 | 2 | 8921·26 | 61·95 | 47·25 | 535·66 | 4·577 | 0·02557 | 0·2185 | 39·108 | 32 |
| 33 | 3 | 9108·71 | 63·25 | 48·55 | 535·03 | 4·486 | 0·02561 | 0·2229 | 39·047 | 33 |
| 34 | 4 | 9299·32 | 64·58 | 49·88 | 534·40 | 4·400 | 0·02564 | 0·2273 | 39·001 | 34 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| +35 | 495·66 | 9493·07 | 65·92 | +51·22 | 533·78 | 4·314 | 0·02568 | 0·2318 | 38·940 | +35 |
| 36 | 6 | 9690·04 | 67·29 | 52·59 | 533·13 | 4·234 | 0·02571 | 0·2362 | 38·894 | 36 |
| 37 | 7 | 9890·75 | 68·68 | 53·98 | 532·52 | 4·157 | 0·02574 | 0·2413 | 38·850 | 37 |
| 38 | 8 | 10093·91 | 70·09 | 55·39 | 531·89 | 4·068 | 0·02578 | 0·2458 | 38·789 | 38 |
| 39 | 9 | 10300·88 | 71·53 | 56·83 | 531·26 | 3·989 | 0·02582 | 0·2507 | 38·729 | 39 |
| +40 | 500·66 | 10511·16 | 72·99 | +58·29 | 530·63 | 3·915 | 0·02585 | 0·2554 | 38·484 | +40 |
| 41 | 1 | 10724·95 | 74·48 | 59·78 | 529·99 | 3·839 | 0·02588 | 0·2605 | 38·639 | 41 |
| 42 | 2 | 10942·18 | 75·99 | 61·29 | 529·36 | 3·766 | 0·02591 | 0·2655 | 38·595 | 42 |
| 43 | 3 | 11162·93 | 77·52 | 62·82 | 528·73 | 3·695 | 0·02594 | 0·2706 | 38·550 | 43 |
| 44 | 4 | 11387·21 | 79·08 | 64·38 | 528·10 | 3·627 | 0·02697 | 0·2757 | 38·499 | 44 |
| +45 | 505·66 | 11615·12 | 80·66 | +65·96 | 527·47 | 3·559 | 0·02600 | 0·2809 | 38·461 | +45 |
| 46 | 6 | 11846·64 | 82·27 | 67·57 | 526·83 | 3·493 | 0·02603 | 0·2863 | 38·417 | 46 |
| 47 | 7 | 12081·80 | 83·90 | 69·20 | 526·20 | 3·428 | 0·02606 | 0·2917 | 38·373 | 47 |
| 48 | 8 | 12320·71 | 85·56 | 70·86 | 525·57 | 3·362 | 0·02609 | 0·2974 | 38·328 | 48 |
| 49 | 9 | 12563·36 | 87·25 | 72·55 | 524·93 | 3·303 | 0·02612 | 0·3027 | 38·284 | 49 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| +50 | 510·66 | 12809·91 | 88·96 | +74·26 | 524·30 | 3·242 | 0·02616 | 0·3084 | 38·226 | +50 |
| 51 | 1 | 13080·21 | 90·70 | 76·00 | 523·66 | 3·182 | 0·02620 | 0·3143 | 38·167 | 51 |
| 52 | 2 | 13314·43 | 92·46 | 77·76 | 523·03 | 3·124 | 0·02623 | 0·3201 | 38·124 | 52 |
| 53 | 3 | 13572·52 | 94·25 | 79·55 | 522·39 | 3·069 | 0·02626 | 0·3258 | 38·080 | 53 |
| 54 | 4 | 13834·64 | 96·07 | 81·37 | 521·76 | 3·012 | 0·02629 | 0·3320 | 38·037 | 54 |
| +55 | 515·66 | 14100·74 | 97·92 | +83·22 | 521·12 | 2·958 | 0·02632 | 0·3380 | 37·994 | +55 |
| 56 | 6 | 14370·92 | 99·80 | 85·10 | 520·48 | 2·905 | 0·02636 | 0·3442 | 37·936 | 56 |
| 57 | 7 | 14645·18 | 101·70 | 87·00 | 519·84 | 2·853 | 0·02639 | 0·3505 | 37·893 | 57 |
| 58 | 8 | 14923·98 | 103·64 | 88·94 | 519·20 | 2·802 | 0·02643 | 0·3568 | 37·835 | 58 |
| 59 | 9 | 15206·28 | 105·60 | 90·90 | 518·57 | 2·753 | 0·02646 | 0·3632 | 37·793 | 59 |
| +60 | 520·66 | 15493·09 | 107·59 | +92·89 | 517·93 | 2·705 | 0·02651 | 0·3697 | 37·736 | +60 |
| 61 | 1 | 15784·23 | 109·61 | 94·91 | 517·29 | 2·658 | 0·02654 | 0·3762 | 37·678 | 61 |
| 62 | 2 | 16079·67 | 111·66 | 96·96 | 516·65 | 2·610 | 0·02658 | 0·3831 | 37·622 | 62 |
| 63 | 3 | 16379·51 | 113·75 | 99·05 | 516·01 | 2·565 | 0·02661 | 0·3898 | 37·579 | 63 |
| 64 | 4 | 16683·75 | 115·86 | 101·16 | 515·37 | 2·520 | 0·02665 | 0·3968 | 37·523 | 64 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| +65 | 525·66 | 16992·50 | 118·03 | +103·33 | 514·73 | 2·476 | 0·02668 | 0·4039 | 37·481 | +65 |
| 66 | 6 | 17305·70 | 120·18 | 105·48 | 514·09 | 2·433 | 0·02671 | 0·4110 | 37·439 | 66 |
| 67 | 7 | 17623·45 | 122·38 | 107·68 | 513·45 | 2·389 | 0·02675 | 0·4189 | 37·383 | 67 |
| 68 | 8 | 17945·89 | 124·62 | 109·92 | 512·81 | 2·351 | 0·02678 | 0·4254 | 37·341 | 68 |
| 69 | 9 | 18272·81 | 126·89 | 112·16 | 512·16 | 2·310 | 0·02682 | 0·4329 | 37·285 | 69 |
| +70 | 530·66 | 18604·53 | 129·19 | +114·49 | 511·52 | 2·272 | 0·02686 | 0·4401 | 37·230 | +70 |
| 71 | 1 | 18941·00 | 131·54 | 116·84 | 510·87 | 2·233 | 0·02689 | 0·4479 | 37·188 | 71 |
| 72 | 2 | 19282·21 | 133·90 | 119·20 | 510·22 | 2·194 | 0·02693 | 0·4558 | 37·133 | 72 |
| 73 | 3 | 19628·32 | 136·31 | 121·61 | 509·58 | 2·153 | 0·02697 | 0·4645 | 37·079 | 73 |
| 74 | 4 | 19979·22 | 138·74 | 124·04 | 508·93 | 2·122 | 0·02700 | 0·4712 | 37·037 | 74 |
| +75 | 535·66 | 20335·16 | 141·22 | +126·52 | 508·29 | 2·087 | 0·02703 | 0·4791 | 36·995 | +75 |
| 76 | 6 | 20696·00 | 143·72 | 129·02 | 507·64 | 2·052 | 0·02706 | 0·4873 | 36·954 | 76 |
| 77 | 7 | 21061·85 | 146·26 | 131·56 | 506·99 | 2·017 | 0·02710 | 0·4957 | 36·900 | 77 |
| 78 | 8 | 21432·82 | 148·84 | 134·14 | 506·34 | 1·995 | 0·02714 | 0·5012 | 36·845 | 78 |
| 79 | 9 | 21808·85 | 151·45 | 136·75 | 505·69 | 1·952 | 0·02717 | 0·5123 | 36·805 | 79 |

## Wood's Table of Saturated Ammonia.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$ | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| +80 | 540·66 | 22190·15 | 154·10 | +139·40 | 505·05 | 1·921 | 0·02721 | 0·5205 | 36·751 | +80 |
| 81 | 1 | 22576·51 | 156·78 | 142·08 | 504·40 | 1·889 | 0·02725 | 0·5294 | 36·696 | 81 |
| 82 | 2 | 22968·88 | 159·50 | 144·80 | 503·75 | 1·858 | 0·02728 | 0·5382 | 36·657 | 82 |
| 83 | 3 | 23365·38 | 162·26 | 147·56 | 503·10 | 1·827 | 0·02732 | 0·5473 | 36·603 | 83 |
| 84 | 4 | 23767·81 | 165·05 | 150·35 | 502·45 | 1·799 | 0·02736 | 0·5558 | 36·549 | 84 |
| +85 | 545·66 | 24175·61 | 167·88 | +153·18 | 501·81 | 1·770 | 0·02739 | 0·5649 | 36·509 | +85 |
| 86 | 6 | 24588·92 | 170·75 | 156·05 | 501·15 | 1·741 | 0·02743 | 0·5744 | 36·456 | 86 |
| 87 | 7 | 25007·80 | 173·66 | 158·96 | 500·50 | 1·714 | 0·02747 | 0·5834 | 36·407 | 87 |
| 88 | 8 | 25432·16 | 176·61 | 161·91 | 499·85 | 1·687 | 0·02751 | 0·5927 | 36·350 | 88 |
| 89 | 9 | 25862·14 | 179·59 | 164·89 | 499·20 | 1·660 | 0·02754 | 0·6024 | 36·311 | 89 |
| +90 | 550·66 | 26297·88 | 183·62 | +167·92 | 498·55 | 1·634 | 0·02758 | 0·6120 | 36·258 | +90 |
| 91 | 1 | 26739·88 | 185·69 | 170·99 | 497·89 | 1·608 | 0·02761 | 0·6219 | 36·219 | 91 |
| 92 | 2 | 27186·56 | 188·79 | 174·09 | 497·24 | 1·583 | 0·02765 | 0·6317 | 36·166 | 92 |
| 93 | 3 | 27639·43 | 191·94 | 177·24 | 496·59 | 1·558 | 0·02769 | 0·6418 | 36·114 | 93 |
| 94 | 4 | 28098·26 | 195·13 | 180·43 | 495·94 | 1·534 | 0·02772 | 0·6518 | 36·075 | 94 |

WOOD'S TABLE OF SATURATED AMMONIA.—(*Continued.*)

| Temperature. | | Pressure Absolute. | | Gauge Pressure, lb. per sq. inch. | Heat of Vaporisation, thermal units. $h$. | Volume of Vapour per lb. cubic feet. $v$. | Volume of Liquid per lb. cubic feet. $v_1$. | Weight of Vapour in lbs. per cubic foot. $w$. | Weight of Liquid in lbs. per cubic foot. $w_1$. | Temperature. Degrees F. |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees F. $t$. | Absolute. $T$. | Lbs. per sq. foot. $P$. | Lbs. per sq. inch. $p$. | | | | | | | |
| +95 | 555·66 | 28563·00 | 198·35 | +183·65 | 495·29 | 1·510 | 0·02776 | 0·6622 | 36·023 | +95 |
| 96 | 6 | 29033·86 | 201·62 | 186·92 | 494·63 | 1·486 | 0·02780 | 0·6729 | 35·971 | 96 |
| 97 | 7 | 29510·69 | 204·94 | 190·24 | 493·97 | 1·463 | 0·02784 | 0·6835 | 35·919 | 97 |
| 98 | 8 | 29993·52 | 208·29 | 193·59 | 493·34 | 1·442 | 0·02787 | 0·6934 | 35·881 | 98 |
| 99 | 9 | 30482·52 | 211·68 | 196·98 | 492·66 | 1·419 | 0·02791 | 0·7047 | 35·829 | 99 |
| +100 | 560·66 | 30977·78 | 215·12 | +200·42 | 492·01 | 1·398 | 0·02795 | 0·7153 | 35·778 | +100 |

TABLE SHOWING REFRIGERATING EFFECT OF ONE CUBIC FOOT OF AMMONIA GAS AT DIFFERENT CONDENSER AND SUCTION (BACK) PRESSURE IN B. T. UNITS —.

*(Professor Siebel, "Compend of Mechanical Refrigeration.")*

| Temperature of Gas in Degrees F. | Corresponding Suction Pressure. lbs. per sq. in. | Temperature of the Liquid in Degrees F. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
| | | Corresponding Condenser Pressure (Gauge) lbs. per square inch. | | | | | | | | |
| | | 103 | 115 | 127 | 140 | 153 | 168 | 184 | 200 | 218 |
| | G. Pres. | | | | | | | | | |
| −25 | 1 | 27·30 | 27·01 | 26·73 | 26·44 | 26·16 | 25·87 | 25·59 | 25·30 | 25·02 |
| −20 | 4 | 33·74 | 33·40 | 33·04 | 32·70 | 32·34 | 31·99 | 31·64 | 31·30 | 30·94 |
| −15 | 6 | 36·36 | 36·48 | 36·10 | 35·72 | 35·34 | 34·96 | 34·58 | 34·20 | 33·82 |
| −10 | 9 | 42·28 | 41·84 | 41·41 | 40·97 | 40·54 | 40·10 | 39·67 | 39·23 | 38·80 |
| −5 | 13 | 48·31 | 47·81 | 47·32 | 46·82 | 46·33 | 45·83 | 45·34 | 44·84 | 44·35 |
| 0 | 16 | 54·88 | 54·32 | 53·76 | 53·20 | 52·64 | 52·08 | 51·52 | 50·96 | 50·40 |
| 5 | 20 | 61·50 | 60·87 | 60·25 | 59·62 | 59·00 | 58·37 | 57·75 | 57·12 | 56·50 |
| 10 | 24 | 68·66 | 67·97 | 67·27 | 66·58 | 65·88 | 65·19 | 64·49 | 63·80 | 63·10 |
| 15 | 28 | 75·88 | 75·12 | 74·35 | 73·59 | 72·82 | 72·06 | 71·29 | 70·53 | 69·76 |
| 20 | 33 | 85·15 | 84·30 | 83·44 | 82·59 | 81·73 | 80·88 | 80·02 | 79·17 | 78·31 |
| 25 | 39 | 95·50 | 94·54 | 93·59 | 92·63 | 91·68 | 90·72 | 89·97 | 88·81 | 87·86 |
| 30 | 45 | 106·21 | 105·15 | 104·09 | 103·03 | 101·97 | 100·91 | 99·95 | 98·79 | 97·73 |
| 35 | 51 | 115·69 | 114·54 | 123·39 | 112·24 | 111·09 | 109·94 | 108·79 | 107·64 | 106·49 |

## Useful Efficiency of Ammonia.

*(Denton and Schroeter.)*

| No. of Test. | Temperature in Degrees Fahr. Corresponding to Pressure of Vapour. | | Ice Melting Capacity per Pound of Coal, assuming Three Pounds per Hour per Horse-power. | | |
|---|---|---|---|---|---|
| | Condenser. | Suction. | Theoretical Friction * included. | Actual. | Per Cent. Loss due to Cylinder Super-heating. |
| 1 | 72·3 | 26·6 | 50·4 | 40·6 | 19·4 |
| 2 | 70·5 | 14·3 | 37·6 | 30·0 | 20·2 |
| 3 | 69·2 | 0·5 | 29·4 | 22·0 | 25·2 |
| 4 | 68·5 | 11·8 | 22·8 | 16·1 | 29·4 |
| 24 | 84·2 | 15·0 | 27·4 | 24·2 | 11·7 |
| 26 | 82·7 | −3·2 | 21·6 | 17·5 | 19·0 |
| 25 | 84·6 | −10·8 | 18·8 | 14·5 | 22·9 |

* Friction taken at figures observed in the tests, which range from 14 per cent. to 20 per cent. of the work of the steam cylinder.

## Liquid Receiver.

This is a vessel placed between the condenser and the expansion valve to receive and store the liquefied ammonia. The dimensions of the liquid receiver should be sufficient to hold about ½ gallon for each ton of refrigerating capacity in 24 hours. The liquid receiver also serves as an additional oil trap. If, as is sometimes the case, the liquid receiver is intended to act as a storage vessel for all the charge of liquefiable ammonia in the plant in case of repairs, etc., it should be provided with valves, which should not be closed when the receiver is over two-thirds full. Preferably the receiver should be made large enough to contain twice the charge of ammonia to avoid explosions. The receiver is provided with oil and liquid gauges.

TABLE SHOWING EFFICIENCY OF AMMONIA COMPRESSION PLANT UNDER DIFFERENT CONDITIONS.

(*Professor Siebel, "Compend of Mechanical Refrigeration."*)

| NO. OF TEST— | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Temperature of refrigerated brine | Inlet, deg. Fahr. | 43·194 | 28·344 | 13·952 | −0·279 |
| | Outlet, deg. Fahr. | 37·054 | 22·885 | 8·771 | −5·879 |
| Specific heat of brine (per unit of volume) | | 0·8608 | 0·8508 | 0·8427 | 0·8374 |
| Quantity of brine circulated per hour, cubic feet | | 1039·38 | 908·84 | 633·89 | 414·98 |
| Cold produced, B.T.U. per hour | | 342·909 | 263·950 | 172·776 | 121·474 |
| Temperature of cooling water in condenser | Inlet, deg. Fahr. | 48·832 | 49·476 | 48·931 | 49·098 |
| | Outlet, deg. t.c. F. | 66·724 | 68·013 | 67·282 | 67·267 |
| Quantity of cooling water per hour in cubic feet | | 338·76 | 260·83 | 187·506 | 139·99 |
| Heat eliminated by condenser B.T.U. per hour | | 378·358 | 301·404 | 214·796 | 158·926 |
| I.H.P. in compressor cylinder | | 13·82 | 14·29 | 13·53 | 11·98 |
| I.H.P. in steam engine cylinder | | 15·80 | 16·47 | 15·28 | 14·24 |
| Consumption of steam per hour in lbs. | | 311·51 | 335·98 | 305·87 | 278·79 |
| Cold produced per hour B.T.U. | Per I.H.P. in comp. cyl. | 24·813 | 18·471 | 12·770 | 10·140 |
| | Per I.H.P. in steam cyl. | 21·703 | 16·026 | 11·307 | 8·530 |
| | Per lb. of steam | 1100·8 | 785·6 | 564·9 | 435·82 |

## PROPERTIES OF SATURATED CARBONIC ACID GAS.

*(Denton and Jacobus.*)*

| Temperature of Ebullition in Degrees Fahr. | Absolute Pressure in lbs per sq. in. | Total Heat reckoned from 32° Fahr. | Heat of Liquid reckoned from 32° Fahr. | Latent Heat of Evaporation. | Heat Equivalent of External Work. | Increase of Volume during Evaporation. | Density of Vapour or Weight of One Cubic Foot. |
|---|---|---|---|---|---|---|---|
| −22 | 210 | 98·35 | −37·80 | 136·15 | 16·20 | 0·4158 | 2·321 |
| −13 | 249 | 99·14 | −32·51 | 131·65 | 16·04 | 0·3459 | 2·759 |
| −4 | 292 | 99·88 | −26·91 | 126·79 | 15·80 | 0·2901 | 3·265 |
| 5 | 342 | 100·58 | −20·92 | 121·50 | 15·50 | 0·2435 | 3·853 |
| 14 | 39[illegible] | 101·21 | −14·49 | 115·70 | 15·08 | 0·2042 | 4·535 |
| 23 | 457 | 101·81 | −7·56 | 109·37 | 14·58 | 0·1711 | 5·331 |
| 32 | 525 | 102·35 | 0·00 | 102·35 | 13·93 | 0·1426 | 6·265 |
| 41 | 599 | 102·84 | 8·32 | 94·52 | 13·14 | 0·1177 | 7·374 |
| 50 | 680 | 103·24 | 17·60 | 85·64 | 12·15 | 0·0960 | 8·708 |
| 59 | 768 | 103·59 | 28·22 | 75·37 | 10·91 | 0·0763 | 10·356 |
| 68 | 864 | 103·84 | 40·86 | 62·98 | 9·29 | 0·0577 | 12·482 |
| 77 | 968 | 103·95 | 57·06 | 46·89 | 7·06 | 0·0391 | 15·475 |
| 86 | 1080 | 103·72 | 84·44 | 19·28 | 2·95 | 0·0147 | 21·519 |

* *Transformed to English units from a metric table computed by Prof. Schröter.*

## Saturated Sulphur Dioxide Gas.

(*Ledoux.*)

| Temperature of Ebullition in deg. F. $t$ | Absolute Pressure in lbs. per sq. in. $P \div 144$ | Total Heat reckoned from 32° Fahr. $\lambda$ | Heat of Liquid reckoned from 32° Fahr. $q$ | Latent Heat of Evaporation. $r$ | Heat equivalent of External Work. $A\,Pu$ | Increase of Volume during Evaporation. $u$ | Density of Vapour or Weight of One Cubic Foot. |
|---|---|---|---|---|---|---|---|
| Deg. Fahr. | lbs. | B.T.U. | B.T.U. | B.T.U. | B.T.U. | Cubic Feet. | lbs. |
| −22 | 5·56 | 157·43 | −19·56 | 176·90 | 13·59 | 13·17 | 0·076 |
| −13 | 7·23 | 158·64 | −16·30 | 174·95 | 13·83 | 10·27 | 0·097 |
| −4 | 9·27 | 159·84 | −13·05 | 172·89 | 14·05 | 8·12 | 0·123 |
| 5 | 11·76 | 161·03 | −9·79 | 170·82 | 14·26 | 6·50 | 0·153 |
| 14 | 14·74 | 162·20 | −6·53 | 168·73 | 14·46 | 5·25 | 0·190 |
| 23 | 18·31 | 163·36 | −3·27 | 166·63 | 14·66 | 4·29 | 0·232 |
| 32 | 22·53 | 164·51 | 0·00 | 164·51 | 14·84 | 3·54 | 0·282 |
| 41 | 27·48 | 165·65 | 3·27 | 162·38 | 15·01 | 2·93 | 0·340 |
| 50 | 33·25 | 166·78 | 6·55 | 160·23 | 15·17 | 2·45 | 0·407 |
| 59 | 39·93 | 167·90 | 9·83 | 158·07 | 15·32 | 2·07 | 0·483 |
| 68 | 47·61 | 168·99 | 13·11 | 155·89 | 15·46 | 1·75 | 0·570 |
| 77 | 56·39 | 170·09 | 16·39 | 153·70 | 15·59 | 1·49 | 0·669 |
| 86 | 66·36 | 171·17 | 19·69 | 151·49 | 15·71 | 1·27 | 0·780 |
| 95 | 77·64 | 172·24 | 22·98 | 149·26 | 15·82 | 1·09 | 0·906 |
| 104 | 90·31 | 173·30 | 26·28 | 147·02 | 15·91 | 0·91 | 1·046 |

## Useful Efficiency of Sulphur Dioxide.

(*Schroeter.*)

| No. of Test. | Temperature in Degrees Fahr. corresponding to Pressure of Vapour. | | Ice Melting Capacity per Pound of Coal, assuming Three Pounds per Hour per Horse-power. | | |
|---|---|---|---|---|---|
| | Condenser | Suction | Theoretical Friction * included | Actual. | Per Cent. Loss due to Cylinder Super-heating |
| 11 | 77·3 | 28·5 | 41·3 | 33·1 | 19·9 |
| 12 | 76·2 | 14·4 | 31·2 | 24·1 | 22·8 |
| 13 | 75·2 | −2·5 | 23·0 | 17·5 | 23·9 |
| 14 | 80·6 | −15·9 | 16·6 | 10·1 | 39·2 |

* Friction taken at figures observed in the tests which range from 14 per cent. to 20 per cent. of the work of the steam cylinder.

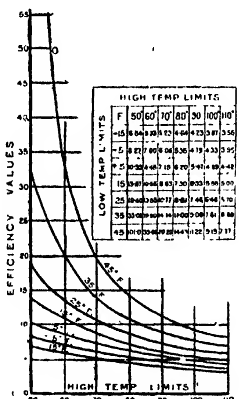



Fig. 21.—Diagram giving Efficiency Curves of a Perfect Refrigerating Machine at Various Limits of Temperature.—(*Murray, Inst. of Engrs. and Shipbuilders, Scotland,* 1897.)

TABLE SHOWING PROPERTIES OF SATURATED VAPOUR OF ETHER.

(*Professor Siebel, "Compend of Mechanical Refrigeration."*)

| Temperature, Degrees Fahr. | Pressure in lbs. per square inch. | Heat of the Liquid. | Total Heat. | Heat of Vaporisation. | Heat equivalent of internal work. | Heat equivalent of external work. | Specific Volume. | Weight in lbs. of one cubic foot. |
|---|---|---|---|---|---|---|---|---|
| | | B. T. Units. | B. T. Units. | B. T. Units. | B. T. Units. | B. T. Units. | | |
| 32 | 3·54 | 0·00 | 376·00 | 376·00 | 345·80 | 30·20 | 1·278 | 0·048 |
| 50 | 5·51 | 21·28 | 393·76 | 372·48 | 341·48 | 31·00 | 0·844 | 0·073 |
| 68 | 8·31 | 42·80 | 411·12 | 368·32 | 336·52 | 31·80 | 0·574 | 0·107 |
| 86 | 12·20 | 64·56 | 428·00 | 363·44 | 330·88 | 32·56 | 0·401 | 0·154 |
| 104 | 17·46 | 86·42 | 444·44 | 357·92 | 324·60 | 33·32 | 0·287 | 0·232 |
| 122 | 24·32 | 88·76 | 460·44 | 351·68 | 317·64 | 34·04 | 0·210 | 0·294 |
| 140 | 33·17 | 131·20 | 476·00 | 344·80 | 310·12 | 34·68 | 0·158 | 0·392 |
| 158 | 44·32 | 153·92 | 491·12 | 337·20 | 301·96 | 35·24 | 0·120 | 0·515 |
| 176 | 58·13 | 176·84 | 505·76 | 328·92 | 293·28 | 35·64 | 0·093 | 0·705 |
| 194 | 74·96 | 200·00 | 520·00 | 320·00 | 284·12 | 35·68 | 0·073 | 0·848 |
| 212 | 95·25 | 223·44 | 532·76 | 310·32 | 274·48 | 35·84 | 0·057 | 1·074 |
| 230 | 119·51 | 247·08 | 547·12 | 300·04 | 264·52 | 35·32 | 0·005 | 1·350 |
| 248 | 148·44 | 270·96 | 560·00 | 289·04 | 254·28 | 34·76 | 0·036 | 1·703 |

The following particulars regarding an ether machine are given * by Mr. Lightfoot as being the result of actual experiments made in this country, and serving to show what may be expected under ordinary conditions :—

| | |
|---|---|
| Production of ice per twenty-four hours .. | 15 tons. |
| ,, ,, per hour .. .. .. | 1,400 lbs. |
| Heat abstracted in ice-making, per hour .. | 245,000 units ** |
| Indicated horse-power in steam cylinder, excluding that required for circulating the cooling water and for working cranes, etc. | 83 I.H.P. |
| Indicated horse-power in ether pump .. | 46½ I.H.P. |
| Thermal equivalent of work in ether pump, per hour .. .. .. .. .. | 119,261 units ** |
| Ratio of work in pump to work in ice-making | 1 to 2·05 |
| Temperature of water entering condenser | 52° Fahr. |

Mr. Frederick Colyer, C.E., M.I.C.E., states † that he obtained the following results with a first-class apparatus when testing the working of some of the leading ether machines, viz.: "In an ether machine made by Messrs. Siebe, Gorman and Co., capable of cooling 3,200 gallons of water from 60° down to 50°, or abstracting 320,000 heat units ** per hour, the average experiments gave 4,250 gallons per hour cooled to 10° Fahr. The temperature of the water at the inlet was 54°, and that of the water used for condensing purposes was the same. The maximum cooling effected was 449,437 heat units ** abstracted per hour, being from 35 to 40 per cent. above the nominal power of the machine. The condensing water used per hour was 1,262 gallons, or about 3-10ths of a gallon for every gallon of water cooled. The coal consumed was 3¼ cwts. per hour; it was of indifferent quality, or the consumption would have been smaller. The steam cylinder was 21 in. diameter and 27 in. stroke; the air-pump 24 in. diameter and 27 in. stroke. The speed of the engine was 58 revolutions per minute, with 48 lbs. of steam cut off at one-third of the stroke. The indicated power of the engine was 53 horse-power, and of the air-pump 29·2 horse-power. The boiler was 7 ft. diameter and 24 ft. long, and gave an ample supply of steam."

* "Proceedings, Institution of Mechanical Engineers," 1886, p. 214.

** A thermal unit is that amount of heat required to raise the temperature of 1 lb. of water 1° by the Fahr. scale when at 39·4°.

† "Proceedings, Institution of Mechanical Engineers," 1886, p. 248.

## Efficiency of Ether Machines.

Output of 15 tons of ice in twenty four hours. Abstraction of heat per hour, 245,000 B.T.U. Indicated horse-power of engine, 83; of which 46 I.H.P. was used for the ether compressor, balance in pumping water, working cranes, friction, etc. Temperature of cooling water, 52°.

Ice production, about 8·3 tons of ice per ton of coal consumed.

## Pictet's Liquid.

| Temperature Degrees Fahr. | Pressure (Absolute) in Atmospheres. | Temperature Degrees Fahr. | Pressure (Absolute) in Atmospheres. |
|---|---|---|---|
| −22 | 0·77 | 50 | 2·55 |
| −13 | 0·89 | 50 | 2·98 |
| −4 | 0·98 | 68 | 3·40 |
| −2·2 | 1·00 | 77 | 3·92 |
| 5 | 1·18 | 86 | 4·45 |
| 14 | 1·34 | 95 | 5·05 |
| 23 | 1·60 | 104 | 5·72 |
| 32 | 1·83 | 113 | 6·30 |
| 41 | 2·20 | 122 | 6·86 |

## Formula for calculating the Amount of Air delivered per Hour by Cold-air Machines, when the Revolutions and the Size of the Compressors are known.

(*Haslam's Catalogue of "Ice-making and Refrigerating Machinery."*)

$$\text{Air discharged per hour} = \frac{A \times N \times 2R \times S \times 60}{1728} \times C$$

Where A = area of each compressor, in inches.
N = number of compressors.
2R = strokes per minute (or twice the revolutions).
60 = minutes per hour.
S = stroke in inches.
1728 = cubic inches in one foot.
C = factor of efficiency which is taken as 0·8 for short strokes, and 0·85 for long strokes.

## SECTION II.

### COLD STORAGE.

COLD storage may be defined as the preservation of perishable articles by keeping them in rooms or chambers maintained constantly at a low temperature by refrigeration; and refrigeration may be defined as the maintenance of any place at a lower temperature than that of the atmosphere.

A most important point in the construction of a cold store is the insulation, and it is almost superfluous to observe that the aim is to render this latter as perfect as possible, so as to afford as great a protection as is practicable against the escape of the cold air from the interior and the transmission of heat from the exterior.

The refrigeration of cold stores may be carried out on the brire circulation system, the direct expansion system, and the air-blast system. In the first, refrigerated or cooled brine is circulated through cooling pipes, or their equivalent, arranged in the cold store; and in the second the ammonia or refrigerating medium is allowed to expand direct in the above pipes. In the third, or air-blast system, air reduced to a low temperature by passing it over cooled pipes or surfaces, or by means of a cold-air machine, is admitted to the store.

The dimensions of cold stores vary, from that of a few cubic feet space, such as those in private houses, hotels, butchers' shops, etc., up to those of several millions of cubic feet. In the case of a large store it is found most advantageous to arrange for the delivery of goods to or from the store to take place from the highest part of the building, as by this means greater obstacles are offered to the transmission of heat from the exterior to the interior

of the store, and also to the escape of the cold air therefrom, which latter, owing to its being heavier than the surrounding atmosphere, and to its consequent tendency to sink to the lowest level, will not escape from above, whilst it does so readily from any open aperture at a lower level.

### AMOUNT OF REFRIGERATION REQUIRED.

The refrigeration required will be governed by the size of the store, the amount of and frequency with which the goods are brought into the store and removed from it, the temperature of the goods, and their specific heat, the mean external temperature, the greater or lesser perfection of the insulation, and various other matters, which render it totally impossible to lay down any hard-and-fast rules.

A very usual practice is to provide 1 foot run of 2-inch pipe for every 7 cubic feet of space contained in the store, but sometimes the proportion used is as much as one to five, whilst again it is occasionally reduced to one to twelve. For refrigerating meat, in which case it is not desirable to cool the exterior too rapidly before the interior has had time to cool to a certain extent, the best proportion to employ is one to ten.

### AMOUNT OF REFRIGERATING PIPES NECESSARY FOR CHILLING, STORAGE, AND FREEZING CHAMBERS.

*Chilling-rooms or Chambers*, refrigerated on the direct expansion system, 1 ft. run of 2-in. piping for each 14 c. ft. of space; on the brine-circulation system, 1 ft. run of 2-in. piping for each 8 c. ft. of space.

*Freezing-rooms or Chambers*, refrigerated on the direct expansion system, 1 ft. run of 2-in. piping for each 8 c. ft. of space; on the brine-circulation system, 1 ft. run for each 3 c. ft. of space.

*Storage-rooms or Chambers*, refrigerated on the direct expansion system, 1 ft. run of 2-in. piping for each 45 c. ft. of space; on the brine-circulation system, 1 ft. run of 2-in. piping for each 15 c. ft. of space.

THE FOLLOWING TABLE GIVES THE EXTREME LIMITS OF CUBIC FEET OF SPACE PER RUNNING FOOT OF 2-INCH PIPING.—*American Practice.*

| | |
|---|---|
| Breweries—Medium insulation. | |
| Chip and Stock Rooms .. .. .. | 1 to 22 |
| Fermenting and Settling Rooms .. .. | 1 „ 20 |
| Packing Rooms .. .. .. .. | 1 „ 18 |
| Hop Rooms .. .. .. .. .. | 1 „ 25 |
| Packing House. | |
| Chill Rooms for Beef .. .. .. | 1 „ 12 |
| Hogs .. .. .. .. .. .. | 1 „ 10 |
| Freezing Rooms .. .. .. .. | 1 „ 6 or 7 |
| Cold Storage. | |
| Cold Storage Rooms.. .. .. .. | 1 „ 25 or 30 |
| Cold Storage House and Freezing Rooms.. | 1 „ 8 |
| For Eggs, brine preferred .. .. .. | 1 „ 12 |
| Cold Storage .. .. .. .. .. | 1 „ 25 |
| Ice Storage .. .. .. .. .. | 1 „ 20 |
| Fish Freezing (Direct Expansion) .. .. | 1 „ 2 |

*The following five tables are given by Prof. Siebel in the "Compend of Mechanical Refrigeration."*

LINEAL FEET OF 1-INCH PIPING REQUIRED PER CUBIC FOOT OF COLD STORAGE SPACE.

| Size of Building in Cubic Feet, more or less. | Insulation. | Temperature, Degrees Fahr. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0° | 10°. | 20°. | 30°. | 40°. | 50° |
| 100 | Excellent. | 3·0 | 1·78 | 0·48 | 0·36 | 0·24 | 0·15 |
| | Poor. | 6·0 | 1·50 | 0·90 | 0·66 | 0·48 | 0·30 |
| 1,000 | Excellent. | 1·0 | 0·26 | 0·16 | 0·12 | 0·08 | 0·05 |
| | Poor. | 2·0 | 0·50 | 0·30 | 0·22 | 0·16 | 0·10 |
| 10,000 | Excellent. | 0·61 | 0·16 | 0·10 | 0·075 | 0·055 | 0·035 |
| | Poor. | 1·2 | 0·33 | 0·20 | 1·15 | 0·11 | 0·07 |
| 30,000 | Excellent. | 0·5 | 0·13 | 0·08 | 0·06 | 0·040 | 0·025 |
| | Poor. | 1·0 | 0·25 | 0·15 | 0·11 | 0·03 | 0·05 |
| 100,000 | Excellent. | 0·38 | 0·10 | 0·06 | 0·045 | 0·03 | 0·009 |
| | Poor. | 0·75 | 0·20 | 0·12 | 0·09 | 0·06 | 0·018 |

NOTE.—The above quantities of pipe refer to direct expansion, and should be made one and one-half times to twice the length for brine circulation. To find the corresponding lengths of $1\frac{1}{4}$-inch pipe, divide by 1·25 or multiply by 0·8; of 2-inch pipe divide by 1·08, or multiply by 0·55.

NUMBER OF CUBIC FEET COVERED BY ONE FOOT OF 1-INCH IRON PIPE.

| Size of Building in Cubic Feet more or less. | Insulation. | TEMPERATURE, DEGREES FAHR. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0° | 10°. | 20° | 30°. | 40° | 50° |
| 100 | Excellent. | 0·3 | 1·3 | 2·1 | 2·8 | 4·2 | 7·0 |
| | Poor. | 0·15 | 0·7 | 1·1 | 1·5 | 2·1 | 3·5 |
| 1,000 | Excellent. | 1·0 | 4·0 | 6·0 | 8·4 | 12·1 | 20·0 |
| | Poor. | 0·5 | 2·0 | 3·2 | 4·5 | 6·2 | 10·0 |
| 10,000 | Excellent. | 1·7 | 6·0 | 10·0 | 13·0 | 18·0 | 28·0 |
| | Poor. | 0·85 | 3·0 | 5·0 | 6·5 | 9·0 | 14·0 |
| 30,000 | Excellent. | 2·0 | 8·0 | 14·0 | 18·0 | 25·0 | 40·0 |
| | Poor. | 1·0 | 4·0 | 7·0 | 9·0 | 13·0 | 20·0 |
| 100,000 | Excellent. | 2·6 | 10·0 | 17·0 | 22·0 | 33·0 | 110·0 |
| | Poor. | 1·3 | 5·0 | 8·5 | 11·0 | 17·0 | 55·0 |

NOTE.—The above figures refer to direct expansion, from one-half to two-thirds of the spaces only would be covered by the same amount of pipe in case of brine circulation. To find the corresponding amounts of cubic feet of space which would be covered by one lineal foot of $1\frac{1}{4}$-in. pipe, multiply by 1·25 or divide by 0·8; of 2-in. pipe, multiply by 1·08 or divide by 0·55.

NUMBER OF CUBIC FEET COVERED BY 1-TON REFRIGERATING CAPACITY FOR 24 HOURS.*

| Size of Building in Cubic Feet, more or less. | Insulation. | TEMPERATURE, DEGREES FAHR. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0°. | 10°. | 20°. | 30°. | 40°. | 50°. |
| 100 | Excellent. | 150 | 600 | 800 | 1000 | 1600 | 3000 |
| | Poor. | 70 | 300 | 400 | 600 | 900 | 2000 |
| 1,000 | Excellent. | 500 | 2500 | 3000 | 4000 | 6000 | 12000 |
| | Poor. | 250 | 1500 | 1800 | 2500 | 5000 | 10000 |
| 10,000 | Excellent. | 700 | 3000 | 4000 | 6000 | 9000 | 18000 |
| | Poor. | 300 | 1800 | 2500 | 3500 | 7000 | 14000 |
| 30,000 | Excellent. | 1000 | 5000 | 6000 | 8000 | 13000 | 25000 |
| | Poor. | 500 | 3000 | 3500 | 5000 | 11000 | 20000 |
| 100,000 | Excellent. | 1500 | 7500 | 9000 | 14000 | 20000 | 40000 |
| | Poor. | 800 | 4500 | 5000 | 8000 | 16000 | 35000 |

* Allowing an ample margin of refrigerating power for opening of doors, etc.

## TABLL OF REFRIGERATING CAPACITIES.

| SIZE OF BUILDING. | | | | Number of Cubic Feet per Ton of Refrigeration at Temperature given. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Temperatures. | | | | | | |
| Dimensions of Building. | Contents: Cubic feet. | Surface in Square feet. | Ratio: Cubic feet to Square feet. | 0° | 8° | 16° | 24° | 32° | 40° | 48° |
| 5 × 4 × 5 | 100 | 130 | 1·3 | 000 | 1,100 | 1,300 | 1,500 | 1,700 | 1,000 | 2,100 |
| 8 × 10 × 10 | 800 | 520 | 0·65 | 1,800 | 2,200 | 2,600 | 3,000 | 3,400 | 3,800 | 4,200 |
| 10 × 10 × 10 | 1,000 | 600 | 0·6 | 1,940 | 2,376 | 2,808 | 3,240 | 3,670 | 4,104 | 4,530 |
| 25 × 40 × 10 | 10,000 | 3,300 | 0·33 | 3,600 | 4,400 | 5,200 | 6,000 | 6,700 | 7,600 | 8,400 |
| 20 × 50 × 20 | 20,000 | 4,800 | 0·24 | 4,860 | 5,040 | 7,020 | 8,100 | 9,180 | 10,260 | 11,340 |
| 30 × 50 × 20 | 30,000 | 6,200 | 0·206 | 5,670 | 6,930 | 8,190 | 9,650 | 10,710 | 11,970 | 13,230 |
| 40 × 50 × 20 | 40,000 | 7,600 | 0·19 | 6,300 | 7,700 | 9.100 | 10,500 | 11,900 | 13,300 | 14,700 |
| 50 × 50 × 20 | 50,000 | 9,000 | 0·18 | 6,480 | 7,920 | 0,360 | 10,800 | 12,240 | 13,680 | 15,120 |
| 60 × 50 × 20 | 60,000 | 10,400 | 0·17 | 6,840 | 8,360 | 9,880 | 11,400 | 12,920 | 14,440 | 15,960 |
| 80 × 50 × 20 | 80,000 | 13,200 | 0·165 | 7 200 | 8,800 | 10,700 | 12,000 | 13,600 | 15,200 | 16,800 |
| 100 × 50 × 20 | 100,000 | 16,000 | 0·16 | 7,200 | 8,800 | 10,400 | 12,000 | 13,600 | 15,200 | 16,800 |
| 100 × 100 × 20 | 200,000 | 28,000 | 0·14 | 8,100 | 9,900 | 11,700 | 13,000 | 15,300 | 17,—0 | 18,900 |
| 100 × 100 × 30 | 300,000 | 32,000 | 0·106 | 11,030 | 13,486 | 15,938 | 18,390 | 20,840 | 23,290 | 25,740 |
| 100 × 100 × 40 | 400,000 | 36,000 | 0·09 | 13,050 | 15,050 | 18,850 | 21,750 | 24,650 | 27,550 | 30,450 |
| 100 × 100 × 50 | 500,000 | 40,000 | 0·08 | 14,400 | 17,600 | 20,800 | 24,000 | 27,200 | 30,400 | 33,600 |
| 100 × 100 × 60 | 600,000 | 44,000 | 0·073 | 16,200 | 19,800 | 23,400 | 27,000 | 30,600 | 34,200 | 37,800 |
| 100 × 100 × 70 | 700,000 | 48,000 | 0·07 | 16,650 | 20,350 | 24,050 | 27,750 | 31,450 | 35,150 | 38,850 |
| 100 × 100 × 80 | 800,000 | 52,000 | 0·065 | 18,000 | 22,000 | 26,000 | 30,000 | 34,000 | 38,000 | 42,000 |
| 100 × 100 × 90 | 900,000 | 56,000 | 0·062 | 18,900 | 23,100 | 27,300 | 31,500 | 35,700 | 29,900 | 44,100 |
| 100 × 100 × 100 | 1,000,000 | 60,000 | 0·06 | 19,350 | 23,650 | 27,950 | 32,250 | 36,550 | 40,850 | 45,150 |
| Lineal feet. | Cubic feet. | Square feet. | Ratio. | Cubic feet. | Cubic feet. | Cubic feet. | Cubic feet. | Cubic feet. | Cubic feet. | Cubic feet. |

## ROUGH ESTIMATE OF REFRIGERATION IN BREWERIES.

A ready method of obtaining a rough estimate in tons of the amount of refrigeration required in a brewery is to divide the capacity of the brewery in barrels by 4.

## REFRIGERATING CAPACITY IN B.T.U. REQUIRED PER CUBIC FOOT OF STORAGE ROOM IN TWENTY-FOUR HOURS.

| Size of Building in Cubic Feet, more or less. | Insulation. | TEMPERATURE, DEGREES FAHR. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0°. | 10°. | 20°. | 30°. | 40°. | 50° |
| 100 | Excellent. | 1,800 | 480 | 360 | 284 | 180 | 95 |
| | Poor. | 4,000 | 960 | 480 | 470 | 330 | 140 |
| 1,000 | Excellent. | 550 | 110 | 95 | 70 | 47 | 24 |
| | Poor. | 1,100 | 190 | 165 | 110 | 55 | 28 |
| 10,000 | Excellent. | 400 | 95 | 70 | 47 | 30 | 16 |
| | Poor. | 900 | 160 | 110 | 81 | 40 | 20 |
| 30,000 | Excellent. | 280 | 55 | 47 | 35 | 22 | 11 |
| | Poor. | 550 | 95 | 81 | 55 | 26 | 14 |
| 100,000 | Excellent. | 190 | 38 | 30 | 20 | 14 | 7 |
| | Poor. | 350 | 63 | 55 | 35 | 18 | 4 |

## APPROXIMATE AMOUNT OF REFRIGERATION REQUIRED FOR COLD STORE CARRYING MIXED PRODUCE.—(*Ruddick*).

| | | | | | | |
|---|---|---|---|---|---|---|
| Space | 10,000 | cubic feet, | Refrigeration required | 10 | tons per | day. |
| ,, | 30,000 | ,, | ,, ,, | 20 | ,, | ,, |
| ,, | 50,000 | ,, | ,, ,, | 30 | ,, | ,, |
| ,, | 75,000 | ,, | ,, ,, | 40 | ,, | ,, |
| ,, | 100,000 | ,, | ,, ,, | 50 | ,, | ,, |

## VARIATION IN CAPACITY, ETC., OF A REFRIGERATING MACHINE.

The following diagram (Fig. 22) and table (on page 81)

showing the variation in capacity, etc., of a refrigerating machine, and the economy of direct expansion, is drawn up by the De La Vergne Company:—

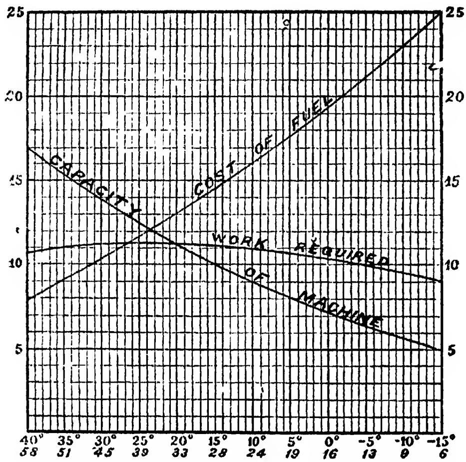



FIG. [illegible].—Diagram showing Variation in Capacity, Cost of Fuel, and Work Required of a Refrigerating Machine.—(*De La Vergne Company.*)

In the above diagram the line marked "capacity of machine" shows the diminished capacity as the back pressure is reduced. If the machine has a capacity of ten tons at a return pressure of 28 pounds, as shown by vertical height of the curve, it has a capacity of five tons only with a return pressure of six pounds. Under the same circumstances the cost of fuel per ton is increased in the ratio of the vertical heights to the curve marked "cost of fuel" namely, from 14·5 to 25. In other words, the cost per ton is nearly doubled while the capacity is halved. The work, as seen by the curve marked "work required," diminishes very slowly.

This shows very plainly the economy of direct expansion. The ammonia in the coils of the brine tank must be cooled below the brine or the directly expanded ammonia. If the difference be 10°, say 5° instead of 15°, then the capacity of the machine is reduced in the ratio of 10 to 8, or 20 per cent., and the cost for fuel increased in the ratio of from 14·5 to 17·5, or 20 per cent.

These are physical facts which cannot be explained away, and the economy of direct expansion in practice over both brine and air circulation is usually greater than the diagram and table illustrates.

CUBIC FEET OF AMMONIA GAS PER MINUTE TO PRODUCE ONE TON OF REFRIGERATION PER DAY.

CONDENSER.

| | | $p$ | 103 | 115 | 127 | 139 | 153 | 168 | 185 | 200 | 218 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $p$ | $t$ | 65° | 70° | 75° | 80° | 85° | 90° | 95° | 100° | 105° |
| REFRIGERATOR. | 4 | −20° | 5·84 | 5·9 | 5·96 | 6·03 | 6·09 | 6·16 | 6·23 | 6·30 | 6·43 |
| | 6 | −15° | 5·35 | 5·4 | 5·46 | 5·52 | 5·58 | 5·64 | 5·70 | 5·77 | 5·83 |
| | 9 | −10° | 4·66 | 4·73 | 4·76 | 4·81 | 4·86 | 4·91 | 4·97 | 5·05 | 5·08 |
| | 13 | −5° | 4·09 | 4·12 | 4·17 | 4·21 | 4·25 | 4·30 | 4·35 | 4·40 | 4·44 |
| | 16 | 0° | 3·59 | 3·63 | 3·66 | 3·70 | 3·74 | 3·78 | 3·83 | 3·87 | 3·91 |
| | 20 | 5° | 3·20 | 3·24 | 3·27 | 3·30 | 3·34 | 3·38 | 3·41 | 3·45 | 3·49 |
| | 24 | 10° | 2·87 | 2·9 | 2·93 | 2·96 | 2·99 | 3·02 | 3·06 | 3·09 | 3·12 |
| | 28 | 15° | 2·59 | 2·61 | 2·65 | 2·68 | 2·71 | 2·73 | 2·76 | 2·80 | 2·82 |
| | 33 | 20° | 2·31 | 2·34 | 2·36 | 2·38 | 2·41 | 2·44 | 2·46 | 2·49 | 2·51 |
| | 39 | 25° | 2·06 | 2·08 | 2·10 | 2·12 | 2·15 | 2·17 | 2·20 | 2·22 | 2·24 |
| | 45 | 30° | 1·85 | 1·87 | 1·89 | 1·91 | 1·93 | 1·95 | 1·97 | 2·00 | 2·01 |
| | 51 | 35° | 1·70 | 1·72 | 1·74 | 1·76 | 1·77 | 1·79 | 1·81 | 1·83 | 1·85 |

DETERMINATION OF MOISTURE IN AIR.—(*Siebel.*)

The moisture in the atmosphere may be determined by a wet-bulb thermometer, which is an ordinary thermometer, the bulb of which is covered with muslin kept wet, and

which is exposed to the air, the moisture of which is to be ascertained. Owing to the evaporation of the water on the muslin, the thermometer will shortly acquire a stationary temperature, which is always lower than that of the surrounding air (except when the latter is actually saturated with moisture). If $t$ is the temperature of the atmosphere, and $t_1$ the temperature of the wet-bulb thermometer in degrees Celsius, the tension $e$, of the aqueous vapour in the atmosphere, is found by the formula—

$$e = e_1 - 0{\cdot}00077(t-t_1)h_1$$

$e_1$ being the maximum tension of aqueous vapour for the temperature $t_1$ as found in table, and $h$ the barometric length in millimeters. (*See* table, p. 83.)

If $e_2$ is the maximum tension of aqueous vapour for the temperature $t$, the degree of saturation, H, is expressed by—

$$H = \frac{e}{e_2}$$

and the dew point is also readily found in the same table, it being the temperature corresponding to the tension $e$.

## Psychrometers.

Instead of the wet-bulb thermometer alone, it is more convenient to use two exact thermometers combined (one with a wet bulb and the other with a dry bulb, to give the temperature of the air), to determine the hygrometric condition of the atmosphere, or of the air in a room. Instruments on this principle can be readily bought, and are called psychrometers. If they are arranged with a handle, so that they can be whirled around, they are called "sling psychrometers." These permit a quicker correct reading of the wet-bulb thermometer than the plain psychrometer, in which the thermometers are stationary and are impracticable at a temperature below 32° Fahr., while the sling instrument can be read down to 27° Fahr.

The following table can be used to ascertain the degree of saturation or the relative humidity of air :—

RELATIVE HUMIDITY—PER CENT.—(*U.S. Weather Bureau.*)

| $t$ (Dry Ther.) | Difference between the Dry and Wet Thermometers ($t - t_1$). | | | | | | | | | | | | $t$ (Dry Ther.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0°·5 | 1°·0 | 1°·5 | 2°·0 | 2°·5 | 3°·0 | 3°·5 | 4°·0 | 4°·5 | 5°·0 | 5°·5 | 6°·0 | |
| 28 | 94 | 88 | 82 | 77 | 71 | 65 | 60 | 54 | 49 | 43 | 38 | 33 | 28 |
| 29 | 94 | 89 | 83 | 77 | 72 | 66 | 61 | 56 | 50 | 45 | 40 | 35 | 29 |
| 30 | 94 | 89 | 84 | 78 | 73 | 67 | 62 | 57 | 52 | 47 | 41 | 36 | 30 |
| 31 | 95 | 89 | 84 | 79 | 74 | 68 | 63 | 58 | 53 | 48 | 43 | 38 | 31 |
| 32 | 95 | 90 | 84 | 79 | 74 | 69 | 64 | 59 | 54 | 50 | 45 | 40 | 32 |
| 33 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 56 | 51 | 47 | 42 | 33 |
| 34 | 95 | 91 | 86 | 81 | 75 | 72 | 67 | 62 | 57 | 53 | 48 | 44 | 34 |
| 35 | 95 | 91 | 86 | 82 | 76 | 73 | 69 | 65 | 59 | 54 | 50 | 45 | 35 |
| 36 | 96 | 91 | 86 | 82 | 77 | 73 | 70 | 66 | 61 | 56 | 51 | 47 | 36 |
| 37 | 96 | 91 | 87 | 82 | 78 | 74 | 70 | 66 | 62 | 57 | 52 | 48 | 37 |
| 38 | 96 | 92 | 87 | 83 | 79 | 75 | 71 | 67 | 63 | 58 | 54 | 50 | 38 |
| 39 | 96 | 92 | 88 | 83 | 79 | 75 | 72 | 68 | 63 | 59 | 55 | 52 | 39 |
| 40 | 96 | 92 | 88 | 84 | 80 | 76 | 72 | 68 | 64 | 60 | 56 | 53 | 40 |

The hygrometer of Professor Marvin is a sling psychrometer of improved construction.

HYGROMETERS.

While the term "hygrometer" applies to all instruments calculated to ascertain the amount of moisture in the air, it is specifically used to designate instruments on which the degree of humidity can be read off directly on a scale without calculation and table. Their operation is based on the change of the length of a hair, or similar hygroscopic substance under different conditions of humidity.

Table giving weights of aqueous vapour held in suspension by 100 lbs. of pure dry air when saturated, at different temperatures, and under the ordinary atmospheric pressure of 29·9 in. of mercury.—(*Box and Lightfoot.*)

| Temperature. | Weight of vapour. | Temperature. | Weight of vapour. |
|---|---|---|---|
| Fahr. degs. | lbs. | Fahr degs. | lbs. |
| −20 | 0·0350 | 102 | 4·547 |
| −10 | 0·0574 | 112 | 6·253 |
| 0 | 0·0918 | 122 | 8·584 |
| +10 | 0·1418 | 132 | 11·771 |
| 20 | 0·2265 | 142 | 16·170 |
| 32 | 0·379 | 152 | 22·465 |
| 42 | 0·561 | 162 | 31·713 |
| 52 | 0·819 | 172 | 46·338 |
| 62 | 1·179 | 182 | 71·300 |
| 72 | 1·680 | 192 | 122·643 |
| 89 | 2·361 | 202 | 280·230 |
| 92 | 3·289 | 212 | Infinite |

N.B.—The weight in lbs. of the vapour mixed with 100 lbs. of pure air at any given temperature and pressure is given by the formula—

$$\frac{62·3E}{29·9-E} \times \frac{29·9}{p}$$

Where E = elastic force of the vapour at the given temperature, in inches of mercury (to be taken from Tables).

$p$ = absolute pressure in inches of mercury.
= 29·9 for ordinary atmospheric pressure.

CORRECT RELATIVE HUMIDITY FOR A GIVEN TEMPERATURE IN EGG ROOMS.—(*Madison Cooper.*)

| TEMPERATURE IN DEGREES FAHR. | RELATIVE HUMIDITY PER CENT. |
|---|---|
| 28 | 80 |
| 29 | 78 |
| 30 | 76 |
| 31 | 74 |
| 32 | 71 |
| 33 | 69 |
| 34 | 67 |
| 35 | 65 |
| 36 | 62 |
| 37 | 60 |
| 38 | 58 |
| 39 | 56 |
| 40 | 53 |

SPECIFIC HEAT AND COMPOSITION OF VICTUALS.

| | Water. | Solids. | Specific Heat above Freezing Calc. | Specific Heat below Freezing Calc. | Latent Heat of Freezing Calc. |
|---|---|---|---|---|---|
| Lean beef .. | 72·00 | 28·00 | 0·77 | 0·41 | 102 |
| Fat beef .. | 51·00 | 49·00 | 0·60 | 0·34 | 72 |
| Veal .. | 63·00 | 37·00 | 0·70 | 0·39 | 90 |
| Fat pork .. | 39·00 | 61·00 | 0·51 | 0·30 | 55 |
| Eggs .. | 70·00 | 30·00 | 0·76 | 0·40 | 100 |
| Potatoes .. | 74·00 | 26·00 | 0·80 | 0·42 | 105 |
| Cabbages .. | 91·00 | 9·00 | 0·93 | 0·48 | 129 |
| Carrots .. | 83·00 | 17·00 | 0·87 | 0·45 | 118 |
| Cream .. | 59·25 | 30·75 | 0·68 | 0·38 | 84 |
| Milk .. | 87·50 | 12·50 | 0·90 | 0·47 | 124 |
| Oysters .. | 80·38 | 19·62 | 0·84 | 0·44 | 114 |
| White fish .. | 78·00 | 22·00 | 0·82 | 0·43 | 111 |
| Eels .. | 62·07 | 37·93 | 0·69 | 0·38 | 88 |
| Lobsters .. | 76·62 | 23·38 | 0·81 | 0·42 | 108 |
| Pigeons .. | 72·40 | 27·60 | 0·78 | 0·41 | |
| Poultry .. | 73·70 | 26·30 | 0·80 | 0·42 | |

TEMPERATURES ADAPTED FOR THE COLD STORAGE OF VARIOUS ARTICLES.

*Degrees Fahrenheit.*

| Article. | Wallis-Tayler. | Siebel. | Schmidt. | Getty. | Ice and Refrigeration. | Ice and Cold Storage. | Rane. | Madison Cooper. | Douglas. |
|---|---|---|---|---|---|---|---|---|---|
| Ale .. .. .. | — | 33—42 | — | — | — | — | — | — | — |
| Apples .. .. .. | 32—36 | 33 | 32—36 | 32 | 32—36 | 33—36 | — | 31 | 31—36 |
| Apples (Summer) .. | — | — | — | — | — | — | 38—42 | — | — |
| Apples (Winter) .. | — | — | — | — | — | — | 32—35 | — | — |
| Apple and Peach Butter | — | — | — | 40 | — | — | — | 42 | — |
| Asparagus .. .. | 34 | 34 | 34—35 | 34 | 34 | 35 | 34 | 33 | — |
| Bananas .. .. .. | 40—45 | 36—46 | 34 | 35 | 40—45 | 40—45 | — | 36 | — |
| Beans (dried) .. .. | 32—40 | — | — | 32—40 | — | 32—40 | — | 40 | — |
| Beef (fresh) . .. | — | — | — | 37—39 | — | — | — | 35 | 35—39 |
| Beef (frozen) .. .. | 16—24 | — | — | — | — | — | — | — | 16—24 |
| Beef (dried) .. .. | — | — | — | 36—45 | — | — | — | — | — |
| Beer (in casks or barrels) | 33—42 | 33—42 | 33—35 | — | 33—42 | 33—40 | — | — | 33—42 |
| Beer (in bottles).. .. | 45 | 45 | 45 | — | 45 | 45 | — | 45 | 45 |
| Berries (fresh, for ten days) | 36—40 | — | — | 35 | — | 36—40 | — | 40 | — |
| Buckwheat flour .. | 40 | — | — | — | — | 40 | — | 42 | — |
| Butter .. .. .. | 32—38 | 32—35 | 18—25 | 32—35 | 32—38 | 25—30 | — | 14 | 25—38 |
| Butter (to freeze) .. | 20 | — | — | 20 | — | — | — | — | 20 |
| Butterine.. .. .. | 28—35 | — | — | — | — | 35 | — | 20 | 20—35 |
| Cabbages .. .. | 34 | — | — | 33 | — | 35 | — | 32 | — |
| Cantaloupes .. .. | 40 | — | — | — | — | 40 | — | 40 | — |
| Carrots .. .. .. | 34 | — | — | 34 | — | 35 | — | 33 | — |
| Celery .. .. .. | 32—34 | 33—35 | 34—35 | 34 | 32—34 | 35 | — | 32 | — |

TEMPERATURES ADAPTED FOR THE COLD STORAGE OF VARIOUS ARTICLES.—(*Continued*).

| Article. | Wallis Tayler. | Siebel. | Schmidt. | Getty. | Ice and Refrigeration. | Ice and Cold Storage. | Rane. | Madison Cooper | Douglas. |
|---|---|---|---|---|---|---|---|---|---|
| Cheese .. .. .. | 32—33 | 32—33 | 28—34 | 31—32 | 32—33 | 32—33 | — | 35 | 28—35 |
| Cherries .. .. .. | 30—36 | — | — | — | — | — | — | — | — |
| Chestnuts .. .. | 33 | — | — | 33 | — | 33 | — | 40 | — |
| Chocolate (to cool) .. | 40 | — | — | — | — | — | — | — | 40 |
| Cider .. .. .. | 30—40 | 30—40 | 30—35 | — | 30—40 | 35—40 | — | 32 | — |
| Cigars .. .. .. | 35 | — | — | 35 | — | 35 | — | 42 | — |
| Clarets .. .. .. | — | 45—50 | — | — | — | — | — | — | — |
| Corn Meal .. .. | — | — | — | — | — | — | — | 42 | — |
| Corn (dried) .. .. | 35 | — | — | 35 | — | 35 | — | 45 | — |
| Cranberries .. .. | 34—36 | — | — | — | — | 34—36 | — | 33 | — |
| Cream .. .. .. | 35 | — | — | — | — | — | — | — | 35 |
| Cucumbers .. .. | — | — | — | — | — | — | 38—40 | 38 | — |
| Currants .. .. .. | 32—36 | — | — | — | — | — | — | 32 | — |
| Dates .. .. .. | 55 | — | — | — | — | 55 | — | 45 | — |
| Eggs .. .. .. | 33—35 | 32—33 | 31—33 | — | 32—35 | 33—35 | — | 30 | 28—35 |
| Ferns .. .. .. | — | — | — | — | — | — | — | 28 | — |
| Figs .. .. .. | 55 | — | — | 35 | — | — | — | — | — |
| Fish (fresh) .. .. | 25—30 | 25—30 | 20 | 25 | 25—30 | 25—30 | — | 28 | 20—30 |
| Fish (fresh water, frozen) | — | — | — | — | — | — | — | 17 | 17 |
| Fish (salt water, frozen) | — | — | — | — | — | — | — | 14 | 14 |
| Fish (canned) .. .. | 35 | — | — | 35 | — | — | — | — | 35 |
| Fish (dried) .. .. | 35—40 | 35 | 35—36 | 36 | 35 | 35 | — | 40 | 35—40 |

TEMPERATURES ADAPTED FOR THE COLD STORAGE OF VARIOUS ARTICLES.—(*Continued*).

| Article | Wallis-Tayler. | Siebel. | Schmidt. | Getty. | Ice and Refrigeration. | Ice and Cold Storage | Rane. | Madison Cooper. | Douglas. |
|---|---|---|---|---|---|---|---|---|---|
| Fish (to freeze) .. .. | 5 | — | — | — | — | — | — | 5 | 5 |
| Flour, &c. .. .. | — | 40 | 36—40 | 40 | 40 | — | — | — | 36—40 |
| Fruits .. .. .. | 26—55 | — | — | — | — | — | — | — | 32—45 |
| Fruits (dried) .. .. | 35—40 | — | — | 38 | — | 35—40 | — | 40 | 35—40 |
| Fruits (canned) .. .. | 35 | — | — | 35 | — | 35 | — | 30 | 30—35 |
| Furs (undressed) .. | 35 | 35 | — | 35 | 35 | — | — | 35 | 35 |
| Furs (dressed) .. .. | 25—32 | 25—32 | 28—35 | 25—32 | 25—32 | 35 | — | 25 | 25—35 |
| Game (frozen) .. .. | 25—28 | 25—28 | 25—28 | 27 | 25—28 | 25—28 | — | 28 | 25—28 |
| Game (to freeze) .. | 15—28 | — | — | 0—5 | — | 15—28 | — | — | 15—28 |
| Game (long storage) .. | — | — | — | — | — | — | — | 10 | 10 |
| Grapes .. .. .. | 36—38 | 32—40 | 34—36 | 32—40 | 36—38 | 36—38 | 38—40 | 34 | — |
| Ginger ale .. .. | 36 | 36 | — | — | — | 35 | — | 36 | — |
| Hams .. .. .. | 20—35 | — | — | 30—35 | — | — | — | 20 | 20—35 |
| Hogs .. .. .. | — | — | — | 30—33 | — | — | — | — | — |
| Hops .. .. . | 33—40 | 33—36 | 32—40 | 35 | 33—40 | 35—40 | — | 35 | 32—40 |
| Hops (frozen) .. .. | — | — | — | — | — | 28 | — | — | 28 |
| Honey .. .. .. | 45 | 36—40 | 45 | 37—40 | 45 | 45 | — | 45 | 36—45 |
| Lard .. .. .. | — | — | — | 34—45 | — | — | — | — | 34—45 |
| Lemons .. .. .. | 36—40 | 36—45 | 33—36 | 35—45 | 36—40 | 36—40 | — | 38 | 33—45 |
| Liver .. .. .. | — | — | — | 30 | — | — | — | 20 | 20—30 |
| Maple syrup sugar .. | — | — | — | 40—45 | — | — | — | 45 | — |
| Margarine .. .. | — | 35 | 18—25 | — | 35 | — | — | — | 18—35 |

TEMPERATURES ADAPTED FOR THE COLD STORAGE OF VARIOUS ARTICLES.—(*Continued*).

| Article. | Wallis-Tayler. | Siebel. | Schmidt. | Getty. | Ice and Refrigeration. | Ice and Cold Storage. | Rane. | Madison Cooper. | Douglas. |
|---|---|---|---|---|---|---|---|---|---|
| Meat (brined or pickled) | — | — | — | 35—40 | — | — | — | — | 35—40 |
| Meat (canned) .. .. | 35 | — | — | 35 | — | 35 | — | 30 | 30—35 |
| Meat (fresh) .. .. | 34 | 35 | 35—40 | — | 34 | 35 | — | — | 34—40 |
| Melons (for 3 or 4 weeks) | — | — | — | — | — | — | — | 35 | — |
| Milk .. .. . | — | — | — | 32 | — | — | — | — | 32 |
| Mutton (fresh) .. .. | 33—35 | — | — | 33—36 | — | — | — | — | 33—36 |
| Mutton (frozen) .. .. | 25—28 | — | — | — | — | — | — | — | 16—24 |
| Nuts (in shells) .. .. | 35 | 35—38 | 35—40 | 35—38 | 35 | 35 | — | 40 | — |
| Oatmeal .. .. .. | 40 | — | — | — | — | 40 | — | 42 | 40—42 |
| Oleomargarine .. .. | 35 | — | — | — | — | 35 | — | 20 | 20—35 |
| Oil .. .. .. | 35 | — | — | 35 | — | 35 | — | 45 | 35—45 |
| Onions .. .. .. | 34—40 | 32—33 | 36 | 32 | 34—40 | 35—40 | 34—40 | 32 | — |
| Oranges .. .. .. | 45—50 | 36 | 34—[illegible] | 35—36 | 45—50 | 45—50 | — | 34 | 34—40 |
| Oysters .. .. .. | 33—35 | — | — | — | — | 33—35 | — | 33 | 33—35 |
| Oysters (in tubs) .. | 25 | — | — | 35 | — | 25 | — | 35 | — |
| Oysters (in shells) .. | 33 | — | — | 40 | — | 30 | — | 43 | — |
| Ox tails .. .. .. | — | — | — | 32 | — | — | — | — | 32 |
| Parsnips .. .. .. | 34 | — | — | 34 | — | 35 | — | 32 | — |
| Peaches .. .. .. | 45—55 | 35—45 | 34—36 | 35—45 | 45—55 | 45—55 | 36—38 | 36 | 35—45 |
| Pears .. .. .. | 34—36 | 33—36 | 34—36 | 38 | 34—36 | 35 | 33—38 | 33 | 33—36 |
| Peas (dried) .. .. | 40 | — | — | 40 | — | 40 | — | 45 | 40—45 |
| Plums .. .. .. | 32—40 | — | — | — | — | — | 38—40 | 32 | 32—40 |

TEMPERATURES ADAPTED FOR THE COLD STORAGE OF VARIOUS ARTICLES.—(*Continued*).

| Article. | Wallis-Tayler. | Siebel. | Schmidt. | Getty. | Ice and Refrigeration. | Ice and Cold Storage. | Rane. | Madison Cooper. | Douglas. |
|---|---|---|---|---|---|---|---|---|---|
| Porter .. .. .. | — | 33—42 | — | — | — | — | — | — | 33—42 |
| Pork .. .. .. | 34 | — | — | — | — | — | — | — | 34 |
| Potatoes .. .. .. | 36—40 | 34—36 | — | 35 | 36—40 | 36—40 | 36—40 | 34 | 34—40 |
| Poultry (frozen) .. .. | 28—30 | 28—30 | 20—28 | 29 | 28—30 | 28—30 | — | 28 | 28—30 |
| Poultry (to freeze) .. | 18—22 | — | — | 5—10 | — | 18—22 | — | — | 10—18 |
| Poultry (long storage) .. | — | — | — | — | — | — | — | 10 | 35—40 |
| Sardines (canned) .. | 35 | — | — | — | — | 35 | — | 40 | — |
| Sauerkraut .. .. | 35—38 | — | — | 36—38 | — | 35—38 | — | 38 | — |
| Sausage casings .. .. | — | — | — | 30—35 | — | — | — | 20 | 20—35 |
| South African Fruits .. | 35—42 | — | — | — | — | — | — | — | — |
| Strawberries .. .. | 30 | — | — | — | — | — | — | — | — |
| Sugar, &c. .. .. | 40—45 | — | — | — | — | 40—45 | — | 45 | — |
| Sweet corn .. .. | — | — | — | 35 | — | — | — | — | — |
| Syrup .. .. .. | 35 | — | — | 35 | — | 35 | — | 45 | — |
| Tenderloin, butts, ribs .. | — | — | — | 30—35 | — | — | — | — | 30—35 |
| Tomatoes .. .. | 36 | 34—35 | 38—42 | 35 | — | 35 | 38—42 | 42 | 34—42 |
| Tobacco .. .. .. | 35 | — | — | 35 | — | 35 | — | 42 | 35—42 |
| Veal .. .. .. | — | — | — | 32—36 | — | — | — | — | 32—36 |
| Vegetables .. .. | 34—40 | — | — | — | — | — | — | — | 34—40 |
| Water-melons .. .. | 34 | — | — | — | — | 35 | — | 40 | 34—40 |
| Wheatflour .. .. | 40 | — | — | — | — | 40 | — | 42 | — |
| Wines .. .. .. | 40—45 | 40—45 | 40—45 | — | 40—45 | 45—50 | — | 42 | 40—50 |
| Woollens, &c. .. .. | 25—32 | 25—32 | 28—35 | 25—32 | 25—32 | 25—30 | — | — | — |

## Mean Temperatures of Principal Cities of the World.

| CITIES. | Spring. | Summer. | Autumn. | Winter. | Annual. |
|---|---|---|---|---|---|
| | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. |
| **England.** | | | | | |
| Birmingham .. | 48·0 | 62·0 | 50·0 | 34·2 | 48·2 |
| Bristol.. .. | 49·7 | 63·0 | 51·5 | 40·0 | 51·05 |
| Liverpool .. | 48·8 | 62·9 | 51·8 | 39·8 | 50·8 |
| London .. | 49·0 | 62·8 | 51·3 | 39·5 | 50·6 |
| Manchester .. | 48·0 | 62·0 | 50·5 | 34·8 | 48·8 |
| **Scotland.** | | | | | |
| Edinburgh .. | 45·7 | 57·9 | 48·0 | 38·5 | 47·5 |
| Glasgow .. | 47·9 | 60·9 | 50·5 | 39·9 | 49·8 |
| **Ireland.** | | | | | |
| Belfast.. .. | — | — | — | — | 52·1 |
| Dublin .. | — | — | — | — | 50·1 |
| **France.** | | | | | |
| Bordeaux .. | — | — | — | — | 57·0 |
| Boulogne .. | — | — | — | — | 54·4 |
| Marseilles .. | — | — | — | — | 58·3 |
| Nice .. .. | 55·9 | 72·5 | 63·0 | 48·7 | 60·1 |
| Paris .. .. | — | — | — | — | 51·3 |
| **Germany.** | | | | | |
| Berlin .. .. | 46·4 | 63·1 | 47·8 | 30·6 | 47·5 |
| Breslau .. | — | — | — | — | 46·7 |
| Buda Pesth .. | — | — | — | — | 47·5 |
| Dresden .. | — | — | — | — | 49·1 |
| Frankfort .. | — | — | — | — | 49·6 |
| Hamburg .. | — | — | — | — | 48·0 |
| Leipsic .. | — | — | — | — | 46·4 |
| Munich .. | — | — | — | — | 48·4 |
| Trieste .. | 53·8 | 71·5 | 56·6 | 39·5 | 55·8 |
| Vienna .. | 49·5 | 63·9 | 52·8 | 39·9 | — |
| **Italy.** | | | | | |
| Florence .. | — | — | — | — | 59·2 |
| Genoa .. | — | — | — | — | 61·1 |
| Milan .. | — | — | — | — | 55·1 |
| Naples .. | 59·5 | 74·5 | 62·5 | 49·9 | 61·6 |
| Palermo .. | 59·5 | 74·5 | 65·9 | 52·0 | 63·1 |
| Rome . | 57·4 | 73·2 | 61·7 | 46·6 | 59·7 |
| Turin .. | 53·1 | 71·6 | 53·8 | 33·4 | 53·1 |
| Venice .. | — | — | — | — | 55·4 |

MEAN TEMPERATURES OF PRINCIPAL CITIES OF THE WORLD.—(*Continued.*)

| CITIES. | Spring. | Summer. | Autumn. | Winter. | Annual. |
|---|---|---|---|---|---|
| | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. |
| SPAIN & PORTUGAL. | | | | | |
| Barcelona .. | — | — | — | — | 63·0 |
| Madrid .. | 57·6 | 74·1 | 56·7 | 42·1 | 57·6 |
| Lisbon .. | 59·9 | 71·1 | 62·5 | 52·3 | 61·4 |
| SWITZERLAND. | | | | | |
| Berne .. | 45·8 | 60·4 | 47·3 | 30·4 | 46·0 |
| Geneva .. | — | — | — | — | 52·7 |
| HOLLAND. | | | | | |
| Amsterdam .. | — | — | — | — | 49·9 |
| Rotterdam .. | — | — | — | — | 51·0 |
| BELGIUM. | | | | | |
| Brussels .. | — | — | — | — | 50·7 |
| NORWAY & SWEDEN. | | | | | |
| Christiania .. | 39·2 | 59·5 | 42·4 | 25·2 | 41·7 |
| Stockholm .. | 38·3 | 61·0 | 43·8 | 25·4 | 42·1 |
| DENMARK. | | | | | |
| Copenhagen .. | 43·7 | 63·0 | 48·5 | 31·5 | 46·8 |
| RUSSIA. | | | | | |
| Moscow .. | 43·3 | 62·6 | 34·9 | 13·5 | 38·5 |
| Nicolaief .. | 49·3 | 72·2 | 50·0 | 25·9 | 48·7 |
| St. Petersburg.. | 35·1 | 60·3 | 40·5 | 16·6 | 38·3 |
| Warsaw .. | 44·6 | 63·5 | 46·4 | 27·5 | 45·5 |
| TURKEY. | | | | | |
| Bucharest .. | — | — | — | — | 46·4 |
| Constantinople. | 51·8 | 73·4 | 60·4 | 40·6 | 56·7 |
| PALESTINE. | | | | | |
| Jerusalem .. | 60·6 | 72·6 | 66·3 | 49·6 | 62·2 |
| EGYPT. | | | | | |
| Cairo .. | 71·6 | 84·6 | 74·3 | 58·5 | 72·3 |
| ALGERIA. | | | | | |
| Algiers .. | 63·0 | 74·5 | 70·5 | 50·4 | 64·6 |
| Tunis .. | — | — | — | — | 68·8 |

MEAN TEMPERATURES OF PRINCIPAL CITIES OF THE WORLD.—(*Continued*)

| CITIES. | Spring. | Summer. | Autumn. | Winter | Annual. |
|---|---|---|---|---|---|
| | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. |
| NORTH AMERICA. | | | | | |
| Baltimore .. | 60·0 | 83·0 | 64·6 | 43·5 | 54·9 |
| Boston .. | 48·0 | 66·0 | 53·0 | 28·0 | 49·0 |
| Chicago .. | 52·8 | 74·5 | 61·3 | 38·5 | 45·9 |
| Cincinnati .. | 63·2 | 81·8 | 66·4 | 46·6 | 54·7 |
| Mexico .. | 53·6 | 63·5 | 65·1 | 60·2 | 60·5 |
| Montreal .. | 44·2 | 69·1 | 47·1 | 17·5 | 43·7 |
| New Orleans .. | 73·0 | 84·0 | 72·0 | 58·0 | 72·0 |
| New York .. | 50·0 | 72·0 | 56·0 | 33·0 | 53·0 |
| Philadelphia .. | 52·0 | 76·0 | 57·0 | 31·0 | 55·0 |
| Quebec .. | — | — | — | — | 40·3 |
| San Francisco .. | 58·0 | 59·0 | 60·0 | 53·0 | 57·5 |
| St. Louis .. | 84·6 | 67·8 | 44·6 | 46·0 | 55·0 |
| Washington .. | 69·0 | 79·0 | 58·0 | 38·0 | 59·0 |
| SOUTH AMERICA. | | | | | |
| Buenos Aires .. | 59·4 | 73·0 | 64·6 | 52·5 | 62·5 |
| Lima .. .. | 63·0 | 73·2 | 69·6 | 59·0 | 66·2 |
| Quito .. .. | 60·3 | 60·1 | 62·5 | 59·7 | 60·1 |
| Rio Janeiro .. | 72·5 | 79·0 | 71·5 | 68·5 | 73·6 |
| Valparaiso .. | — | — | — | — | 64·0 |
| EAST INDIES. | | | | | |
| Bombay .. | — | — | — | — | 81·3 |
| Calcutta .. | 82·6 | 83·3 | 80·0 | 67·8 | 78·4 |
| Madras .. | — | — | — | — | 81·9 |
| WEST INDIES. | | | | | |
| Havanna .. | — | — | — | — | 79·1 |
| Kingstown .. | 78·3 | 81·3 | 80·0 | 76·3 | 79·0 |
| Port of Spain . | — | — | — | — | 81·5 |
| CHINA. | | | | | |
| Canton .. | 69·8 | 82·0 | 72·9 | 54·8 | 69·8 |
| Pekin .. .. | 56·6 | 77·8 | 54·9 | 29·0 | 52·6 |
| AUSTRALASIA. | | | | | |
| Melbourne .. | — | — | — | — | 57·0 |
| Paramatta .. | 66·6 | 73·9 | 64·8 | 54·5 | 64·6 |
| Sydney .. | — | — | — | — | 65·8 |
| CANARY ISLANDS. | | | | | |
| Funchal .. | 63·5 | 70·0 | 67·6 | 61·3 | 65·7 |
| NEW ZEALAND. | | | | | |
| Auckland .. | 60·1 | 66·7 | 58·0 | 53·5 | 59·6 |

MEAN TEMPERATURE BY SEASONS AND EXTREMES, FOR THE YEAR, OF TWENTY STATIONS IN THE ARGENTINE REPUBLIC.—(*Degrees Fahrenheit.*)

(*Especially compiled by the Argentine Meteorological Office.*)

| Station. | Summer. | Autumn. | Winter. | Spring. | Annual. | Extremes. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Max. | Min. |
| *Capital of the Republic.* | | | | | | | |
| Buenos Aires .. .. .. | 73·4 | 62·6 | 51·8 | 61·4 | 62·3 | 104·0 | 28·4 |
| *Province of Buenos Aires.* | | | | | | | |
| Bahia Blanca .. .. .. | 71·6 | 59·0 | 47·0 | 59·5 | 59·3 | 105·8 | 23·0 |
| *Province of Santa-Fé.* | | | | | | | |
| Rosario .. .. .. | 76·5 | 62·0 | 50·5 | 63·1 | 63·0 | 111·1 | 17·7 |
| *Province of Entre-Rios.* | | | | | | | |
| Paraná .. .. .. | 76·5 | 66·2 | 55·4 | 66·2 | 66·1 | 107·6 | 30·2 |
| Concordia .. .. .. | 77·5 | 65·0 | 54·8 | 65·0 | 65·6 | 107·6 | 30·2 |
| *Province of Corrientes.* | | | | | | | |
| Corrientes .. .. .. | 79·4 | 71·0 | 61·3 | 71·0 | 70·7 | 107·6 | 37·4 |
| *Province of Córdoba.* | | | | | | | |
| Córdoba .. .. .. | 73·4 | 61·3 | 51·8 | 64·4 | 62·7 | 111·1 | 15·0 |
| *Province of Tucumán.* | | | | | | | |
| Tucumán .. .. .. | 75·2 | 65·6 | 57·8 | 68·0 | 66·6 | 111·1 | 26·6 |
| *Province of Salta.* | | | | | | | |
| *Salta* .. .. .. .. | 71·6 | 62·6 | 54·2 | 66·2 | 63·6 | 95·0 | 24·8 |
| *Province of Santiago del Estero.* | | | | | | | |
| Santiago del Estero .. .. | 80·6 | 69·2 | 58·5 | 72·8 | 70·3 | 109·4 | 28·4 |

MEAN TEMPERATURE BY SEASONS AND EXTREMES, FOR THE YEAR, OF TWENTY STATIONS IN THE ARGENTINE REPUBLIC.—(*Degrees Fahrenheit.*) (*Continued.*)

(*Especially compiled by the Argentine Meteorological Office.*)

| Station. | Summer. | Autumn. | Winter. | Spring. | Annual. | Extremes. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Max. | Min. |
| *Province of Mendoza.* | | | | | | | |
| Mendoza .. .. .. | 74·6 | 60·8 | 48·2 | 64·4 | 62·0 | 107·6 | 17·6 |
| *Province of San Juan.* | | | | | | | |
| San Juan .. .. .. | 78·8 | 64·4 | 51·2 | 68·0 | 65·4 | 111·1 | 28·4 |
| *Province of Jujuy.* | | | | | | | |
| Jujuy .. .. .. .. | 78·2 | 70·4 | 59·5 | 72·8 | 70·2 | 104·0 | 30·2 |
| *Province of Catamarca.* | | | | | | | |
| Andalgalá .. .. .. | 78·2 | 66·2 | 53·6 | 69·2 | 66·8 | 104·0 | 28·4 |
| *Province of San Luis.* | | | | | | | |
| San Luis .. .. .. | 74·0 | 59·5 | 49·5 | 63·2 | 61·6 | 102·2 | 23·0 |
| *Province of Rioja.* | | | | | | | |
| Rioja .. .. .. .. | 76·3 | 66·8 | 54·6 | 71·4 | 67·3 | 109·4 | 32·0 |
| *Territorio Nacional Chubut.* | | | | | | | |
| Rawson .. .. .. | 68·5 | 54·2 | 42·8 | 57·2 | 55·7 | 102·2 | 14·0 |
| *Territorio Nacional Neuquén.* | | | | | | | |
| Chos Malal .. .. .. | 71·6 | 56·6 | 45·2 | 57·2 | 57·6 | 102·2 | 14·0 |
| *Territorio Nacional Misiones.* | | | | | | | |
| Posadas .. .. .. | 79·2 | 72·2 | 59·6 | 73·2 | 71·0 | 100·4 | 35·6 |
| *Territorio Nacional Formosa.* | | | | | | | |
| Formosa .. .. .. | 80·0 | 71·0 | 63·1 | 71·6 | 71·4 | 104·0 | 30·2 |

## COLD STORAGE CHARGES (*England*).

*Cambria Cold Storage and Ice Co., Ltd.*

### MEAT.

| | First 24 Hours. | Each succeeding 24 hours. | Per Week |
|---|---|---|---|
| Beef, Quarters, each .. .. | 1/- .. | 6d. .. | 2/- |
| Sheep and Lambs, each .. .. | 6d. .. | 3d. .. | 1/6 |
| Pigs and Calves, each .. .. | 1/- .. | 6d. .. | 2/- |
| Beasts' Heads (with tongues), each | 1½d. per week or any part thereof. | | |
| ,, (without ,, ), ,, | 1d. | ,, | ,, |
| Sheeps' Heads and Plucks / Beasts' Livers .. .. / Beasts' Plucks, &c. .. ,, | 1d. | ,, | ,, |
| Beasts' Tails, per doz. .. .. | 4d. | ,, | ,, |
| Pieces of Meat, in packages .. | ⅛d. per lb. | ,, | ,, |

Minimum Charge, 3d.

### FISH, GAME, AND POULTRY.

Fish (wet), small quantities 9d. per cwt. per week or any part thereof.
,, large quantities 6d. ,, ,, ,,
Kippers & Finnon, per box 2d. each and upwards per week or any part thereof.
Loose Fish .. .. ..2d. each and upwards per week or any part thereof.
Poultry and Game.. ..1/- per cwt. per week or any part thereof.
Frozen Poultry, in large quantities .. ..20/- per ton for 28 days ,,
Chickens, loose .. ..1½d. per couple per week ,,
Rabbits, in hampers ..9d. per cwt. per week ,,
Rabbits, loose .. ..1d. per couple per week ,,
Rabbits, Frozen, in cases, small quantities, 6d. per case per week or any part thereof.
Rabbits, Frozen, large quantities, 17/6 per ton for 28 days or any part thereof.
Pheasants, 1½d. per brace 1st week, 1d. per brace each succeeding week.
Partridge and Grouse, 1d. per brace per week or any part thereof.
Hares, Turkeys and Geese, 2d. each ,,

Minimum Charge, 3d.

### PROVISIONS.

Butter, small quantities, 6d. per cwt. per week or any part thereof.

| | | | | | | |
|---|---|---|---|---|---|---|
| ,, | | ,, | 20/- per ton for 28 days or any portion thereof. | | | |
| ,, | 2 tons and upwards, | | 16/- | ,, | ,, | ,, |
| Bacon | ,, | ,, | 14/- | ,, | ,, | ,, |
| Cheese | ,, | ,, | 12/6 | ,, | ,, | ,, |
| Lard | ,, | ,, | 15/- | ,, | ,, | ,, |
| Eggs | ,, | ,, | 17/- | ,, | ,, | ,, |

## Conditions of Deposit and Regulations.

### The Conditions of Deposit are as follows :—

The Cambria Cold Storage and Ice Co., Ltd., receive goods on the following conditions only :—

1.—No goods will be given up without the production of a ticket, which is delivered to the person when goods are brought to Stores, or satisfactory evidence of ownership.

2.—All consignments to the Stores must be plainly marked with the owner's name and address, and date.

3.—All payments for storage must be made when the goods are delivered.

4.—The Company will not be responsible for any loss or damage to goods stored by them, through maintaining too high or too low a temperature in the Stores, failure of machinery, fire, or any other cause whatsoever; but the Company will always, and at all times, use their utmost endeavours to prevent any such damage, and will render all assistance in their power to properly preserve and keep goods entrusted to their care.

5.—The Company reserve to themselves the right to refuse any goods that, in the opinion of the Manager, or his representative, are unfit to store.

6.—The Company will hold all goods stored by them subject to a general lien for all debts due by Depositors on account of Storage.

7. Stores open for receiving and delivering goods :—"Week-days, 6 a.m. to 5 p.m.; Saturday, 6 a.m. to 5 p.m., and 10.30 p.m. to 11.30 p.m."

### COLD STORAGE CHARGES (*United States*).

| Substance. | Temperature. Degrees. | Month. | For the Season. | Remarks. |
|---|---|---|---|---|
| Salt meat .. | 32 to 36 | 25 to 35 cents | — | Per tierce. |
| " .. | 32 to 36 | 20 to 25 " | — | Per barrel. |
| Dried beef .. | 32 to 36 | 35 " | — | — |
| Fresh meat .. | 38 | ¼ " | — | Per pound. |
| " .. | 38 | 25 " | — | Per quarter. |
| Veal .. .. | 36 | 25 " | — | Per pound. |
| Lamb . .. | 36 | 15 " | — | " |
| Game .. .. | 32 to 36 | — | 15 cents | " |
| " .. .. | Below 20 | ½ " | — | Per lb. gross. |
| Venison and poultry | Below 20 | ½ " | — | " |
| Ducks, grouse, and quail | 32 to 35 | — | 15 .. | Per dozen. |
| Quails .. .. | Below 20 | — | 15 , | " |
| Fish .. | 25 to 30 | ½ to ¼ " | — | — |
| Storage Room | — | 25 dollars and upwards | — | Per 1,000 cubic feet. |

COLD STORAGE CHARGES.—(*United States.*)

(*Compend of Mechanical Refrigeration.*)

| GOODS AND QUANTITY. | First Month. | Each Succeeding Month. | In Large Quantities. Per Month. | Season Rate per Barrel of 100 lbs. | Season Ends. |
|---|---|---|---|---|---|
| Apples, per bbl. .. .. .. | $0·15 | $0·12½ | $0·12½ | $0·45 | May 1. |
| Bananas, per bunch .. .. .. | 0·15 | 0·10 | 0·10 | — | — |
| Beef, Mutton, Pork, and Fresh Meat, per lb. .. .. .. .. | 0·00¾ | 0·00½ | 0·00⅜ | — | — |
| Beer and Ale, per bbl... .. .. | 0·25 | 0·25 | — | — | — |
| Beer and Ale, per ½ bbl. .. .. | 0·15 | 0·15 | — | — | — |
| Beer and Ale, per ¼ and ⅛ bbl. .. | 0·10 | 0·10 | — | — | — |
| Beer, bottled, per case.. .. ... | 0·10 | 0·10 | — | — | — |
| Beer, bottled, per bbl. .. .. .. | 0·20 | 0·20 | — | — | — |
| Berries, fresh of all kinds, per quart .. | 0·00½ | 0·00⅓ | 0·00⅓ | — | — |
| Berries, fresh of all kinds, per stand .. | 0·10 | — | — | — | — |
| Butter and Butterine, per lb. .. .. | 0·00½ | 0·00¼ | 0·00⅛ | 0·50—0·75 | Jan. 1. |
| Buckwheat Flour, per lb. .. .. | 0·15 | 0·12½ | 0·10 | 0·50 | Oct. 1. |
| Cabbages, per bbl. .. .. .. | 0·25 | 0·25 | 0·20 | — | — |
| Cabbages, per crate .. .. .. | 0·10 | 0·10 | 0·08 | — | — |
| Calves (per doz.) each .. .. .. | 0·10 | — | — | — | — |
| Calves, per lb. .. .. .. .. | 0·00¾ | 0·00½ | 0·00⅜ | — | — |
| Canned and Bottled Goods, per lb. .. | 0·00¼ | 0·00⅛ | 0·00⅛ | — | — |
| Celery, per case.. .. .. .. | 0·15 | 0·10 | 0·10 | — | — |

COLD STORAGE CHARGES.—*United States.* (*Continued.*)

| GOODS AND QUANTITY. | First Month. | Each Succeeding Month. | In Large Quantities. Per Month. | Season Rate per Barrel of 100 lbs. | Season Ends. |
|---|---|---|---|---|---|
| Cheese, per lb. .. .. .. .. | $0·00⅓ | $0·00¼ | $0·00⅛ | $0·50—·60 | Jan. 1. |
| Cherries, per quart .. .. .. | 0·00⅓ | 0·00⅓ | 0·00⅓ | — | — |
| Cider, per bbl. .. .. .. | 0·25 | 0·15 | 0·15 | — | — |
| Cigars, per lb. .. .. .. .. | 0·00⅓ | 0·00¼ | 0·00⅛ | — | — |
| Cranberries, per bbl. .. .. .. | 0·25 | 0·20 | 0·15 | — | — |
| Cranberries, per case .. .. .. | 0·10 | — | — | — | — |
| Corn Meal, per bbl. .. .. .. | 0·15 | 0·12½ | 0·10 | — | — |
| Dried and boneless Fish, etc., per lb... | 0·00 1—5 | 0·00⅓ | 0·00⅛ | 0·50 | Nov. 1. |
| Dried Corn, per bbl. .. .. .. | 0·12½ | 0·10 | 0·10 | — | — |
| Dried and evaporated Apples, per lb. | 0·00⅕ | 0·00 1—10 | — | 0·50 | Nov. 1. |
| Dried Fruit, per lb. .. .. .. | 0·00 1—6 | 0·00⅕ | 0·00⅕ | 0·40—·50 | Nov. 1. |
| Eggs, per case .. .. .. .. | 0·15 | 0·12½ | 0·10 | 0·50—·60 | Jan. 1. |
| Figs, per lb. .. .. .. .. | 0·00⅛ | 0·00⅕ | 0·00 1—10 | — | — |
| Fish, per bbl. .. .. .. .. | 0·20 | 0·18 | 0·15 | 0·75 | Oct. 1. |
| Fish, per tierce .. .. .. .. | 0·15 | 0·13 | 0·12½ | 0·50 | Oct. 1. |
| Fruits, fresh, per crate.. .. .. | 0·25 | 0·20 | 0·20 | — | — |
| Furs, Undressed, hydraulic .. .. | 0·10 | 0·08 | 0·08 | — | — |
| ,, Pressed, per lb. .. .. .. | 0·00½ | 0·00¼ | 0·00¼ | 1·00 | Oct. 1. |
| ,, Dressed, per lb. .. .. .. | 0·03 | 0·02½ | 0·02 | 8·00 | Oct. 1. |
| Ginger Ale, bottled, per bbl. .. .. | 0·20 | 0·15 | 0·15 | — | — |
| Grapes, per lb. .. .. .. .. | 0·00½ | 0·00⅓ | 0·00¼ | 2·00 | May 1. |
| Grapes, per basket .. .. .. | 0·03 | 0·02 | 0·01 | — | — |

COLD STORAGE CHARGES.—*United States.*—(*Continued.*)

| GOODS AND QUANTITY. | First Month. | Each Succeeding Month. | In Large Quantities. Per Month. | Season Rate per Barrel of 100 lbs. | Season Ends. |
|---|---|---|---|---|---|
| Grapes, Malaga, etc., per keg.. | $0·15 | $0 12½ | $0·12½ | $ — | — |
| Hops, per lb. | 0·00⅓ | 0·00¼ | 0·00⅛ | — | — |
| Lard, per tierce. | 0·25 | 0·20 | 0·20 | 1·00 | Nov. 1. |
| Lard Oil, per cask | 0·25 | 0·20 | 0·20 | 1·00 | Nov. 1. |
| Lemons, per box | 0·15 | 0·12½ | 0·10 | 0·50 | Nov. 1. |
| Macaroni, per bbl. | 0·20 | 0·15 | 0·12½ | — | — |
| Maple Sugar, per lb. | 0·00⅓ | 0·00¼ | 0 00⅕ | 0·40—0·50 | Nov. 1. |
| Maple Syrup, per gallon | 0·01½ | 0·01¼ | 0·01 | — | — |
| Meats, fresh, per lb. | 0·00¾ | 0·00½ | 0·00⅗ | — | — |
| Nuts of all kinds, per lb. | 0·00¼ | 0·00 1—5 | 0 00⅛ | 0·40—0·50 | Nov. 1. |
| Oatmeal, per bbl. | 0·20 | 0·15 | 0·12½ | — | — |
| Oil, per cask | 0·25 | 0·20 | — | — | — |
| Oil, per hhd. | 1·00 | 0·80 | — | — | — |
| Oleomargarine, per lb... | 0·00⅓ | 0 00¼ | 0·00⅓ | — | — |
| Onions, per bbl... | 0·15 | 0 12½ | 0·10 | 0·50—0·60 | May 1. |
| Onions, per box.. | 0·12½ | 0·10 | — | — | — |
| Oranges, per box | 0·15 | 0·12½ | 0·10 | 0·50 | Nov. 1. |
| Oysters in tubs, per gal. | 0·05 | 0·04 | — | — | — |
| Oysters in shells, per bbl. | 0·50 | 0·40 | 0·30 | — | — |
| Peaches, per basket | 0·10 | 0 08 | 0·07 | 2·00 | Jan. 1. |
| Pears, per box .. | 0·20 | 0·15 | — | 0·60 | May 1. |
| Pears, per bbl. .. | 0·40 | 0·30 | — | 1·20 | May 1. |

COLD STORAGE CHARGES.—*United States.*—(*Continued.*)

| GOODS AND QUANTITY. | First Month. | Each Succeeding Month. | In Large Quantities. Per Month. | Season Rate per Barrel of 100 lbs. | Season Ends. |
|---|---|---|---|---|---|
| Pigs' Feet, per lb. .. .. .. | $0·00⅓ | $0·00⅓ | $0·00¼ | $1·00 | Nov. 1. |
| Pork, per tierce .. .. .. .. | 0·20 | 0·15 | 0·15 | — | — |
| Potatoes, per bbl. .. .. .. | 0·25 | 0·20 | 0·20 | — | — |
| Preserves, jellies, jams, etc., per lb. .. | 0·00¼ | 0·00⅛ | 0·00⅓ | — | — |
| Provisions, per bbl. .. .. .. | 0·25 | 0·20 | 0·20 | — | — |
| Rice Flour, per bbl. .. .. .. | 0·20 | 0·15 | 0·12½ | — | — |
| Sauerkraut, per cask .. .. .. | 0·25 | 0·20 | 0·15 | 0·60—0·75 | Nov. 1. |
| Sauerkraut, per ½-bbl. .. .. .. | 0·15 | 0·12½ | 0·10 | — | — |
| Syrup, per bbl... .. .. .. | 0·30 | 0·25 | 0·20 | 1·00 | Oct. 1. |
| Tobacco, per lb. .. .. .. | 0·00⅓ | 0·00¼ | 0·00⅛ | — | — |
| Vegetables, fresh, per bbl. .. .. | 0·25 | 0·20 | 0·15 | — | — |
| Vegetables, fresh, per case .. .. | 0·15 | 0·10 | 0·08 | — | — |
| Wine, in wood, per bbl. .. .. | 0·25 | 0·25 | — | — | — |
| Wine, in bottles, per case .. .. | 0·10 | 0·10 | — | — | — |

## Rates for Freezing Poultry, Game, Fish, Meats, Butter, Eggs, etc., United States.

The rates for freezing goods, or for storing goods at a freezing temperature when they are already frozen, are as follows:—

### Poultry, Game, etc., in Unbroken Packages.

Poultry, including turkeys, fowl, chickens, geese, etc., and rabbits, squirrels, and ducks when picked.

Four rates, A, B, C, and D, for storing poultry, and the rate to be charged will be determined by the amount of such goods as may be frozen and stored during a season of six months, usually from October or November 1st to April or May 1st.

Rate A.—For customers storing fifty or more tons of poultry, the rate to be one-third cent per pound for the first month stored, and one-fourth cent per pound for each month or fraction of a month, including the first month, if stored for more than one month.

Rate B.—For customers storing five or more, but less than fifty tons of poultry, the rate to be one-third cent per pound for the first month stored, and one-fourth cent per pound for each month or fraction of a month thereafter.

Rate C.—For customers storing one or more, but less than five tons of poultry, the rate to be three-eighths cent per pound for the first month stored, and one-fourth cent per pound for each month or fraction of a month thereafter.

Rate D.—For customers storing less than one ton of poultry, the rate to be one-half cent per pound for the first month stored, and three-eighths cent per pound for each month or fraction of a month thereafter.

Venison, etc., and ducks when unpicked, one to one-half cent per pound per month, according to quality and length of time stored.

Grouse and partridges, three cents to five cents per pair per month. Woodcock, one cent to two cents per pair per month.

Squabs and pigeons, four cents to six cents per dozen

per month. Quail, plover, snipe, etc., three cents to five cents per dozen per month.

When a portion of the goods is removed from a package, storage to be charged for the whole package as it was received, until the balance of the package is removed from the freezer.

For goods received loose, when to be taken out of the packages in which they are received, or when to be laid out, the following rates to be charged :—

Poultry, including turkeys, chickens, geese, etc., and rabbits and squirrels, one-half cent to one-fourth cent per pound extra, according to quality and length of time stored.

Grouse, partridges, woodcock, squabs, pigeons, quail, plover, and snipe, 50 per cent. more than the rates as above specified.

Ducks weighing less than two pounds each, two cents to three cents each per month. Ducks weighing two pounds or more each, three cents to four cents each per month.

For all kinds of poultry and birds not herein specified, the rate from one cent to one-half cent per pound per month, according to quantity and length of time stored.

### Summer Freezing Rates.

Freezing rates for the summer months, 50 per cent. more than the specified winter rates for the first month stored, and the same as the winter rates for the second and succeeding months.

### Storing Unfrozen Poultry, etc.

For holding poultry, game, etc., which are not frozen, at a temperature which shall be about 30° Fahr., the rate to be one-fifth cent to two-fifths cent per pound according to quantity, for any time not exceeding two weeks.

### Freezing Rates for Fish and Meats.

Salmon, blue fish, and other fresh fish in packages, one-half cent per pound for the first month stored, three-eighths cent per pound per month thereafter.

Fresh fish of all kinds when to be hung up or laid out, three-fourths cent per pound for the first month stored, one-half cent per pound per month thereafter.

Fish in small quantities, 50 per cent. more than the above rates.

Special rates for large lots of large fish.

Scallops, three-fourths cent per pound, gross, per month.

Sweetbreads, and lamb fries, one cent per pound, gross, per month.

Beef, mutton, lamb, pork, veal, tongues, etc., three-fourths cent to one-half cent per pound, net, for the first month stored, one-fourth cent to three-eighths cent per pound per month thereafter.

### Butter Freezing Rates.

For freezing and storing butter in a temperature of 20° Fahr. or lower, the rate to be charged will be determined by the amount of such goods that may be frozen and stored during the season of eight months from April 1st to December 1st, or from May 1st to January 1st. There will be three rates, A, B, and C.

Rate A.—For customers storing thirty-five (35) or more tons of butter, the rate to be fifteen cents per 100 pounds, net, per month.

Rate B.—For customers storing five or more, but less than thirty-five tons of butter, the rate to be eighteen cents per 100 pounds, net, per month.

Rate C.—For customers storing less than five tons of butter, the rate to be twenty-five cents per 100 pounds, net, per month.

### Egg Freezing Rates.

For freezing broken eggs in cans, the charge to be one-half cent per pound, net weight, per month, and for a season of eight months the rate to be one and one-half cents per pound, net weight.

### Rent of Rooms.

For freezing temperatures, four cents to five cents per cubic foot per month.

### Terms of Payment of Cold Storage and Freezing Rates.

All the above rates are to be charged for each month, or fraction of a month, unless otherwise specified; and in all cases fractions of months to be charged as full months.

Charges to be computed in all cases when possible upon the marked weights and numbers of all goods at the time they are received.

All storage bills are due and payable upon the delivery of a whole lot, or balance of a lot of goods, or every three months, when goods are stored more than three months.

Unless special instructions regarding insurance accompany each lot of goods, they are held at owner's risk.

## COLD STORAGE CHARGES (*France*).

*Public Abattoir, Chambéry.*

Rent of cold storage chamber 500 francs (£20) per annum. An ordinary cold storage chamber contains 17 or 18 hooks, each capable of supporting about 100 kilogrammes (220·4 lbs.) of meat, and 17 or 18 S-hooks, each capable of receiving 10 kilogrammes (22·04 lbs.), in small pieces. The weights of the meat suspended from the hooks and S-hooks are never to exceed the above. In all cases where such weights are exceeded the butchers will be held responsible for any damage and breakages which may result.

Where a cold storage chamber is let to a number of persons, the rent to be per hook, at the rate of 40 francs (32 shillings) a year, that is to say, for the time during which the cold store is in operation. The S-hook situated above is included with each hook.

### Cold Air.

Cold air may with advantage be regenerated by being ozonized before use in the cold store. Air which has passed over certain products, notably many fruits, becomes charged with disagreeable and noxious emanations which are destroyed by the action of the ozone, and at the same time the air is sterilized and the formation of the spores of mould peculiar to cold rooms is prevented.

# SECTION III.

## ICE-MAKING AND STORING ICE.

### ICE-MAKING.

ARTIFICIAL ice is either what is known as clear, transparent, or crystal ice, or milky, opaque, or tombstone ice. The latter is generally used where appearance is of no consequence, and cheapness is the main consideration, and it does not necessarily possess any unwholesome qualities, but it has the objection of very considerably reduced keeping powers, and should be used immediately. The opacity of ice is mainly due to rapid freezing preventing the air contained in solution in the water from escaping.

Clear or crystal ice can be made by using distilled or de-aërated water, or by agitation of the water during the freezing process. This latter has been carried out in a number of different ways, of which the most common and practical is the reciprocating movement of agitators or paddles in the ice can or mould, or in the ice-box, accordingly as the can system or the stationary cell system is in use. Many other devices have, however, been used, amongst which may be mentioned the imparting of a rotary motion to the freezer, rods or plungers moving up and down in cans, oscillating rods or agitators, forcing cold air through the freezing water, shaking cans or moulds, removing water and refilling it by pumping, water injection with pressure reduction, taking water from one point of one can and pumping it into another, rotating stirrer or agitator, freezing ice in very cold air, freezing ice very slowly, freezing ice in very thin slabs.

A white core in ice is due to the presence of carbonite of lime and magnesia or other minerals in the water. A red core in ice is due to the separation of oxide of iron in ice which was maintained in solution in the water in the form of carbonate of iron, and the sediment usually comes from

the iron of the plant. Pure distilled, carefully filtered water should be alone used for making ice intended for domestic consumption. The three most used types of ice-making apparatus are those working on the can system, the stationary cell system, and the plate or wall system.

In ice-making, where it is important to secure the maximum production at the minimum cost, it is necessary to work both day and night so as to render the operation a continuous one. Likewise such routine must be followed as will ensure the largest possible output and the best quality. With this purpose in view, great care must be exercised to maintain all the parts of the apparatus perfectly clean, and in first-class working order. A regular and systematic plan of drawing the ice must be settled upon and strictly adhered to, and with this object a distinctive number or letter should be stamped or painted upon each can or mould, and so many drawn regularly per hour.

TABLE GIVING SIZES AND CAPACITIES OF ICE-MAKING PLANTS, ETC.

(*H. H. Kelley, "The Engineer," New York*)

| Tons *per 24 Hours. | Size of Engine. | Revs. | Size of Compressor. | Size of Blocks of Ice. | Gallons of Water per Hour. | Tons of Coal. | No. of Engineers. | No. of Firemen. | No. of Labourers. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 x 9 | 90 | ‡5 x 10 | 8 x 8 x 28 | 5 | ½ | 1 | | |
| 3 | 8 x 16 | 80 | 5 x 15 | 8 x 15 x 28 | 15 | 1 | 2 | 2 | 2 |
| 5 | 10 x 20 | 75 | 6 x 18 | 8 x 15 x 28 | 20 | 1½ | 2 | 2 | 2 |
| 10 | 12 x 30 | 70 | 8 x 20 | 11 x 22 x 28<br>11 x 11 x 28 | 30 | 2 | 2 | 2 | 3 |
| 10½ | 14 x 30 | 65 | 8 x 25 | 11 x 22 x 28<br>11 x 11 x 28 | 35 | 2½ | 2 | 2 | 3 |
| 15 | 14 x 30 | 65 | 10 x 20 | 11 x 22 x 28<br>11 x 11 x 28 | 40 | 3 | 2 | 2 | 4 |
| 20 | 16 x 30 | 55 | 10 x 30 | 11 x 22 x 28<br>11 x 11 x 28 | 50 | 4 | 2 | 2 | 5 |
| 30 | 16 x 42 | 52 | 11 x 30 | 11 x 22 x 28<br>11 x 11 x 28 | 60 | 5 | 2 | 2 | 6 |
| 40 | 18 x 36 | 50 | 12 x 30 | 11 x 11 x 28 | 90 | 6½ | 2 | 2 | 7 |
| 45 | 20 x 36 | 50 | 15 x 30 | 11 x 11 x 28 | 94 | 8 | 2 | 2 | 8 |
| 60 | 24 x 36 | 45 | 16 x 36 | 11 x 11 x 28 | 96 | 10 | 2 | 2 | 9 |
| 80 | 26 x 48 | 45 | 20 x 36 | 11 x 22 x 28 | 100 | 13 | 2 | 2 | 10 |

* 2,000 pounds. ‡ One cylinder.

## DIMENSIONS OF ICE-MAKING TANKS.

Table compiled by E. T. Skinkle, giving sizes of some Freezing Tanks, Piping and Moulds, in actual operation. (*From "Compend. of Mechanical Refrigeration."*)

| Tons. Ice-making Capacity. | No. of Tanks. | SIZES OF TANKS. Length of Tank. Feet & Inches. | Width of Tank. Feet & inches. | Depth of Tank in inches. | Thickness of Plates in inches. | No. of Coils. | Size of Pipe in inches. | No. of Pipes High. | Length of Coils. | Total feet of Pipe in Tank. | Feet of Pipe per ton Ice-making Capacity. | Number of Ice Moulds in Tank. | Size of Moulds in inches. | Net Weight of Ice from each Mould. | Number of Moulds per ton Ice-making Capacity. | Number Hours for Freezing each Mould. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | |
| 2 | 1 | 17—0 | 6—2 | 33 | 3-16 | 7 | 1 | 6 | 15—4 | 644 | 322 | 60 | 8×15×33 | 100 lbs. | 30 | 36 | |
| 3 | 1 | 17—0 | 9—0 | 33 | 3-16 | 10 | 1 | 6 | 15—0 | 900 | 300 | 90 | 8×15×33 | 100 ,, | 30 | 36 | |
| 5 | 1 | 17—0 | 14—9 | 33 | 3-16 | 16 | 1 | 6 | 15—0 | 1,440 | 288 | 150 | 8×15×33 | 100 ,, | 30 | 36 | |
| 10 | 1 | 29—0 | 19—0 | 33 | ¼ | 25 | 1 | 8 | 17—0 | 3,400 | 340 | 192<br>24 | 11×22×33<br>11×11×33 | 200 ,,<br>100 ,, | 20·4 | 48 | |
| 12½ | 1 | 37—6 | 19—0 | 33 | ¼ | 33 | 1 | 8 | 17—0 | 4,488 | 329 | 256<br>32 | 11×22×33<br>11×11×22 | 200 ,,<br>100 ,, | 21·36 | 52·2 | Special. |
| 15 | 1 | 43—0 | 19—0 | 33 | ¼ | 37 | 1 | 8 | 17—0 | 5,032 | 335 | 288<br>36 | 11×22×33<br>11×11×33 | 200 ,,<br>100 ,, | 20·4 | 48 | |
| 20 | 2 | 29—0 | 19—0 | 33 | ¼ | 25 | 1 | 8 | 17—0 | 3,400 | 340 | 192<br>24 | 11×22×33<br>11×11×33 | 200 ,,<br>100 ,, | 20·4 | 48 | * |
| 30 | 2 | 43—0 | 19—0 | 33 | ¼ | 37 | 1 | 8 | 17—0 | 5,032 | 335 | 288<br>36 | 11×22×33<br>11×11×33 | 200 ,,<br>100 ,, | 20·4 | 48 | * |
| 30 | 1 | 43—0 | 30—0 | 48 | ¼ | 35 | 1¼ | 8 | 28—0 | 7,840 | 261 | 480 | 11×22×45 | 300 ,, | 16 | 57·6 | |
| 60 | 2 | 56—0 | 20—0 | 48 | ¼ | 49 | 1¼ | 10 | 18—0 | 8,820 | 294 | 432 | 11×22×45 | 300 ,, | 14·4 | 51·8 | |
| 60 | 2 | 43—0 | 30—0 | 48 | ¼ | 35 | 1¼ | 8 | 28—0 | 7,840 | 261 | 480 | 11×22×45 | 300 ,, | 16 | 57·6 | * |

Average of 1-in. pipe per ton, 327 feet. Average of 1¼-in. pipe per ton, 272 feet.

* Twenty-ton tanks are duplicate 10-ton tanks
Thirty-ton ,, ,, ,, 15 ,, ,,
Sixty-ton ,, ,, ,, 30 ,, ,,
} Dimensions of one tank only are given in each instance.

## Pure Water.

If properly distilled water, or ice made from such water, be evaporated slowly on a piece of platinum foil over a spirit-lamp or a Bunsen gas-burner, there should be no residuum whatever.

In the manufacture of ice intended for domestic consumption, the use of pure water is a matter of paramount importance, consequently it is well to define what pure water is, and as very much the same requirements that are made by authorities with respect to potable water, also apply to ice, we will give some of the demands made in the former case. Pure water is soft, is transparent, has a certain amount of sparkle, is sufficiently aërated, has no matter held in suspension that is visible, is completely tasteless, and is either entirely colourless or has a slight bluish tint. The requirements of some authorities in the United States in this direction—great care being there exercised—are given by Prof. Siebel as follows: "1. Such water should be clear, temperature not above 15° C. 2. It should contain some air. 3. It should contain in 1,000,000 parts: Not more than 20 parts of organic matter. Not more than 0·1 part of albuminoid ammonias. Not more than 0·5 part of free ammonia. 4. It should contain no nitrates, no sulphuretted hydrogen, and only traces of iron, aluminium, and magnesium. Besides the mentioned substances, it should not contain anything that is precipitable by sulphuretted ammonia. 5. It must not contract any odour in closed vessels. 6. It must contain no saprophites and leptothrix, and no bacteria and infusoria in notable quantities. 7. Addition of sugar must cause no development of fungoid growth. 8. On gelatine it must not generate any liquefying colonies of bacteria."

## Simple Rules for ascertaining the Quality of So-called Mineral Water.—(*Frick Company.*)

Water turning blue litmus paper red before boiling, which after boiling will not do so; and if the blue colour can be restored by warming, then it is carbonated (containing carbonic acid).

If it has a sickening odour, giving a black precipitate

with acetate of lead, it is sulphurous (containing sulphuretted hydrogen).

If it gives a blue precipitate with yellow or red prussiate of potash by adding a few drops of hydrochloric or muriatic acid, it is chalybeate (carbonate of iron).

If it restores blue colour to litmus paper after boiling, it is alkaline.

If it has none of the above properties in a marked degree and leaves a large residue after boiling, it is a saline water (containing salts).

### Testing by Reagents.

If water becomes turbid or opaque by using the following reagents, it is not pure:—

With baryta water, indicating carbonic acid.

With chloride of barium, indicates sulphate.

With nitrate of silver, indicates chloride.

With oxalate of ammonia, indicates lime salts.

With sulphide of hydrogen, slightly acid, indicates presence of antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth, and cadmium.

With sulphide of ammonia, alkaloid by ammonia, indicates nickel, cobalt, manganese, iron, zinc, alumina, and chromium.

With chloride of mercury or gold and sulphate of zinc, indicates organic matter.

### Freezing Tank or Box.

These are constructed of sheet iron and steel, and also of wood and cement. The amount of pipe required is about 250 feet of 2-inch pipe, or 350 feet of $1\frac{1}{4}$-inch pipe, or their equivalent per ton of ice per twenty-four hours, in accordance with the temperature of the brine and the capacity of the machine. Less pipe than the above, says Prof. Siebel, is employed in the United States, even as low as 150 feet of 2-inch pipe, and 200 feet of $1\frac{1}{4}$-inch pipe per ton of ice-making capacity (in twenty-four hours), but in that case the back pressure must be carried excessively low, which duly increases the consumption of coal and the wear and tear of the machinery.

The brine in the freezing tank may be cooled on either the brine circulation or the direct expansion system.

The size and length of pipe in the brine tank, it is recommended by the above-mentioned authority, should be arranged in such a manner that each row of moulds or cans is passed by an ammonia pipe on each side, preferably on the wide side of the mould or can. The series of pipes in the ice tank or box are connected by a manifold, the liquid ammonia entering the manifold at the lower extremity, and the vapour leaving by the suction manifold placed at the higher extremity of the refrigerating coils.

When working with the wet vapour of ammonia, the liquid must be admitted at the upper extremity of the refrigerating coils, and be drawn off to the compressor at their lower extremity.

### Brine for Use in Refrigerating and Ice-making Plants.

A brine suitable for the above purpose can be made with from 3 to 5 lbs. of chloride of calcium, or muriate of lime, in accordance with its degree of purity, dissolved in each gallon of water. The density of this solution is about 23° Beaumé, its weight about $13\frac{1}{2}$ lbs. per gallon, and the freezing-point is $-9°$ Fahr. As the above standard of density must be kept up, in order to prevent the brine from becoming congealed in the refrigerator, or the ice-making tanks or boxes, it is desirable to test it periodically with a salinometer.

In the best American practice first quality medium ground salt, preferably in bags for convenience of handling, is employed, the proportions being about 3 lbs. of salt to each gallon of water. The brine is made in a brine mixer, consisting of a water-tight box or tank about 4 ft. × 8 ft. × 2 ft., having a suitably perforated false bottom, and a small compartment, partitioned off at one extremity, communicating with the main compartment through an overflow situated at the upper end of the partition, and fitted with a large strainer, to prevent the passage into the small compartment of salt or foreign bodies. The water is admitted through a perforated pipe situated beneath, and running the full length of the false bottom, and the brine is removed through a pipe from the

upper part of the end compartment, at the lower extremity of which latter pipe is a strainer-box and strainer through which the brine passes before delivery into the brine-tank. A salt gauge, salinometer, or hydrometer is also placed in the small or end compartment.

The salt should be dissolved in the water until it reaches a density of about 90° by the hydrometer. To facilitate dissolution it is desirable to stir the salt in the mixer with some handy implement, the salt being shovelled in as fast as it can be got to dissolve.

By the use of this mixture the settlement of salt on the bottom, and on the coils in the brine tank, which inevitably results when the dissolution is effected directly in the latter, is avoided.

To maintain the strength of the brine it is recommended to suspend bags filled with the salt in the brine tank, or to pass the return brine through the above-described brine maker or mixer.

A cheap and easily constructed apparatus for mixing brine can be made out of an old barrel in which a perforated false bottom is fixed a short distance above the bottom, the water to form the solution being delivered to the space between the two bottoms, and an overflow pipe fitted with a suitable strainer and a well to receive a salinometer being provided near the top to draw off the brine.

SOLUTIONS OF CHLORIDE OF CALCIUM ($CaCl_2$).

(*Manufacturer of Chloride of Calcium, U.S.*)

| Specific Gravity at 64° Fahr. | Degree Beaumé at 64° Fahr. | Degree Salinometer at 64° Fahr. | Per cent. of Chloride of Calcium. | Freezing-point Degrees Fahr. | Ammonia Gauge. Lbs. per square inch at Freezing-point. |
|---|---|---|---|---|---|
| 1·007 | 1 | 4 | 0·943 | +31·20 | 46 |
| 1·014 | 2 | 8 | 1·886 | +30·40 | 45 |
| 1·021 | 3 | 12 | 2·829 | +29·60 | 44 |
| 1·028 | 4 | 16 | 3·772 | +28·80 | 43 |
| 1·035 | 5 | 20 | 4·715 | +28·00 | 42 |
| 1·043 | 6 | 24 | 5·658 | +26·89 | 41 |
| 1·050 | 7 | 28 | 6·601 | +25·78 | 40 |
| 1·058 | 8 | 32 | 7·544 | +24·67 | 38 |
| 1·065 | 9 | 34 | 8·487 | +23·56 | 37 |
| 1·073 | 10 | 40 | 9·430 | +22·09 | 35·5 |

## SOLUTIONS OF CHLORIDE OF CALCIUM ($CaCl_2$).

(*Manufacturer of Chloride of Calcium, U.S.*)

| Specific Gravity at 64° Fahr. | Degree Beaumé at 64° Fahr. | Degree Salinometer at 64° Fahr. | Per cent. of Chloride of Calcium. | Freezing-point Degrees Fahr. | Ammonia Gauge, Lbs. per square inch at Freezing-point. |
|---|---|---|---|---|---|
| 1·081 | 11 | 44 | 10·373 | +20·62 | 34 |
| 1·089 | 12 | 48 | 11·316 | +19·14 | 32·5 |
| 1·097 | 13 | 52 | 12·259 | +17·67 | 30·5 |
| 1·105 | 14 | 56 | 13·202 | +15·75 | 29 |
| 1·114 | 15 | 60 | 14·145 | +13·82 | 27 |
| 1·112 | 16 | 64 | 15·088 | +11·89 | 25 |
| 1·131 | 17 | 68 | 16·031 | + 9·96 | 23·5 |
| 1·140 | 18 | 72 | 16·974 | + 7·68 | 21·5 |
| 1·149 | 19 | 76 | 17·917 | + 5·40 | 20 |
| 1·158 | 20 | 80 | 18·860 | + 3·12 | 18 |
| 1·167 | 21 | 84 | 19·803 | − 0·84 | 15 |
| 1·176 | 22 | 88 | 20·746 | − 4·44 | 12·5 |
| 1·186 | 23 | 92 | 21·689 | − 8·03 | 10·5 |
| 1·196 | 24 | 96 | 22·632 | −11·63 | 8 |
| 1·205 | 25 | 100 | 23·575 | −15·23 | 6 |
| 1·215 | 26 | 104 | 24·518 | −19·56 | 4 |
| 1·225 | 27 | 108 | 25·461 | −24·43 | 1·5 |
| 1·236 | 28 | 112 | 26·404 | −29·29 | $1^{66}$ vacuum |
| 1·246 | 29 | 116 | 27·347 | −35·30 | $5^{66}$ |
| 1·257 | 30 | 120 | 28·290 | −41·32 | $8·5^{66}$ |
| 1·268 | 31 | — | 29·233 | −47·66 | $12^{66}$ |
| 1·279 | 32 | — | 30·176 | −54·00 | $15^{66}$ |
| 1·290 | 33 | — | 31·119 | −44·32 | $10^{66}$ |
| 1·302 | 34 | — | 32·062 | −34·66 | $4^{66}$ |
| 1·313 | 35 | — | 33·000 | −25·00 | 1·5 lbs. |

## PROPERTIES OF SOLUTION OF CHLORIDE OF CALCIUM.

(*Prof. Siebel, "Compend. of Mechanical Refrigeration."*)

| Percentage by Weight. | Specific Heat. | Specific Gravity at 60° Fahr. | Freezing-point Degrees Fahr. | Freezing-point Degrees Cels. |
|---|---|---|---|---|
| 1 | 0·996 | 1·009 | 31 | −0·5 |
| 5 | 0·964 | 1·043 | 27·5 | −2·5 |
| 10 | 0·896 | 1·087 | 22 | −5·6 |
| 15 | 0·860 | 1·134 | 15 | −9·6 |
| 20 | ·834 | 1·182 | 5 | −14·8 |
| 25 | 0·790 | 1·234 | −8 | −22·1 |

## PROPERTIES OF SOLUTION OF CHLORIDE OF CALCIUM ($CaCl_2$).

(*H. J. West & Co., Ltd.*, "*Catalogue of Ice-Making and Refrigerating Machinery.*")

| Degrees on Various Scales. | | | Specific Gravity at 60° Fahr. Water=1. | Percentage of $CaCl_2$ by Weight. | Weight of 1 Gal. of Solution. | | | Specific Heat of Solution. | Freezing Temp. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Salinometer. | Beaumé. | Twaddell. | | | Water, lbs. | $CaCl_2$ lbs. | Total lbs. | | Fahr. | Celsius. |
| 24 | 5 | 9 | 1·043 | 5 | 9·908 | 0·521 | 10·43 | 0·964 | 27·5° | −2·5° |
| 47 | 12 | 17 | 1·087 | 10 | 9·783 | 1·087 | 10·87 | 0·896 | 22·0° | −5·6° |
| 68 | 17 | 27 | 1·134 | 15 | 9·639 | 1·701 | 11·34 | 0·860 | 15·0° | −9·6° |
| 92 | 23 | 36 | 1·182 | 20 | 9·456 | 2·364 | 11·82 | 0·834 | 5·0° | −14·8° |
| 112 | 28 | 46 | 1·234 | 25 | 9·255 | 3·085 | 12·34 | 0·790 | −8·0° | −22·1° |

## PROPERTIES OF SOLUTION OF CHLORIDE OF SODIUM (COMMON SALT).

| Degrees on Various Scales. | | | Specific Gravity at 60° Fahr. Water=1. | Percentage of SALT, by Weight. | Weight of 1 Gal. of Solution. | | | Specific Heat of Solution. | Freezing Temp. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Salinometer. | Beaumé. | Twaddell. | | | Water, lbs. | Salt, lbs. | Total lbs. | | Fahr. | Celsius. |
| 20 | 5 | 7 | 1·037 | 5 | 9·851 | 0·518 | 10·37 | 0·960 | 25·2° | −3·8° |
| 40 | 10 | 15 | 1·073 | 10 | 9·657 | 1·073 | 10·73 | 0·892 | 18·7° | −7·4° |
| 60 | 15 | 23 | 1·115 | 15 | 9·475 | 1·672 | 11·15 | 0·855 | 12·2° | −11·0° |
| 80 | 19 | 30 | 1·150 | 20 | 9·200 | 2·300 | 11·50 | 0·829 | 6·1° | −14·4° |
| 100 | 24 | 38 | 1·191 | 25 | 8·923 | 2·977 | 11·91 | 0·783 | 0·5° | −17·8° |

## Specific Heat of Calcium Chloride Solutions.

(Experiments made for the Pulsometer Engineering Company by the National Physical Laboratory.)

| Temperature. Fahr. | Specific Heat. | | |
| --- | --- | --- | --- |
| | 38 Twaddell. | 40 Twaddell. | 42 Twaddell. |
| −10 .. .. | 0·699 | 0·687 | 0·676 |
| 0 .. .. | 0·704 | 0·692 | 0·681 |
| +10 .. .. | 0·710 | 0·698 | 0·687 |
| 20 .. .. | 0·715 | 0·703 | 0·692 |
| 30 .. .. | 0·721 | 0·709 | 0·698 |
| 40 .. .. | 0·726 | 0·714 | 0·703 |
| 50 .. .. | 0·732 | 0·720 | 0·709 |
| 60 .. .. | 0·737 | 0·725 | 0·714 |

The above may be taken as probably correct to 0·005.

From these results the following tables were calculated :—

| Temperature. Fahr. | Mean specific heat between 60° F. and temperature tabulated. | B.T.U. necessary to cool one gallon at 60° F. to temperature stated. |
|---|---|---|
| *Solution* 38 *Twaddell at* 60° *F.* | | |
| 50° | 0·734 | 87 |
| 40° | 0·731 | 174 |
| 30° | 0·729 | 260 |
| 20° | 0·726 | 346 |
| 10° | 0·723 | 430 |
| 0° | 0·720 | 514 |
| *Solution* 40 *Twaddell at* 60° *F.* | | |
| 50° | 0·723 | 87 |
| 40° | 0·720 | 173 |
| 30° | 0·717 | 258 |
| 20° | 0·714 | 343 |
| 10° | 0·711 | 427 |
| 0° | 0·708 | 510 |
| *Solution* 42 *Twaddell at* 60° *F.* | | |
| 50° | 0·711 | 86 |
| 40° | 0·708 | 171 |
| 30° | 0·706 | 256 |
| 20° | 0·703 | 340 |
| 10° | 0·700 | 423 |
| 0° | 0·698 | 507 |

Inspection of the last column in each of these 3 tables shows that the number of thermal units necessary to cool one gallon of solution through a given range is nearly independent of the density of the solution. Also that the fall of specific heat with falling temperature is so small as to make it justifiable for most commercial purposes to take the specific heat as a constant over the range of temperature 60° F. to 0° F. and the range of density 38 to 42 Twaddell.

Between these limits the capacity for heat of these solutions may be taken as approximately 8·5 Brit. Therm. Units per gallon.

## Comparison of Various Hydrometer Scales.—(*Yaryan.*)

| Degrees Beaumé. | Specific Gravities. Standard adopted by U.S. Chem. Mfg. Ass. 15·5°. Sp. gr. = $\frac{145·04}{145·04—B}$ | Specific Gravities. Modulus 144·38. Custom in France. | Degrees Densimetric 15·5° C. | Degrees Twaddell 60 Fahr. T° = 200 (Sp. gr. — 1). | Degrees Brix. Official Prussian Hydrometer 15·6° C. Sp. gr. = $\frac{400}{400—Bx°}$ | Degrees Beck 12·5° C. Sp. gr. = $\frac{170}{170—Bk°}$ | Degrees Brix Saccharimetric (per cent. Sugar). | Gay-Lussac (Centigrade). Sp. gr. = $\frac{100}{100—C°}$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 1·000 | 1·0000 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| 1 | 1·007 | 1·0070 | 0·7 | 1·4 | 2·8 | 1·2 | 1·8 | 0·4 |
| 2 | 1·014 | 1·0140 | 1·4 | 2·8 | 5·5 | 2·3 | 3·6 | 1·4 |
| 3 | 1·021 | 1·0215 | 2·1 | 4·2 | 8·2 | 3·5 | 5·4 | 2·1 |
| 4 | 1·028 | 1·0285 | 2·8 | 5·6 | 10·9 | 4·6 | 7·1 | 2·7 |
| 5 | 1·036 | 1·0380 | 3·6 | 7·2 | 13·9 | 5·9 | 9·0 | 3·5 |
| 6 | 1·043 | 1·0435 | 4·3 | 8·6 | 16·5 | 7·0 | 10·7 | 4·1 |
| 7 | 1·051 | 1·0510 | 5·1 | 10·2 | 19·4 | 8·3 | 12·6 | 4·8 |
| 8 | 1·058 | 1·0585 | 5·8 | 11·6 | 21·9 | 9·3 | 14·3 | 5·5 |
| 9 | 1·066 | 1·0665 | 6·6 | 13·2 | 24·8 | 10·4 | 16·1 | 6·2 |
| 10 | 1·074 | 1·0745 | 7·4 | 14·8 | 27·5 | 11·7 | 18·0 | 6·9 |
| 11 | 1·082 | 1·0825 | 8·2 | 16·4 | 30·3 | 12·9 | 19·8 | 7·6 |
| 12 | 1·090 | 1·0905 | 9·0 | 18·0 | 33·0 | 14·1 | 21·5 | 8·3 |
| 13 | 1·098 | 1·0990 | 9·8 | 19·6 | 36·0 | 15·2 | 23·3 | 8·9 |
| 14 | 1·107 | 1·1075 | 10·7 | 21·4 | 39·0 | 16·4 | 25·2 | 9·7 |
| 15 | 1·115 | 1·1160 | 11·5 | 23·0 | 41·3 | 17·6 | 27·0 | 10·3 |
| 16 | 1·124 | 1·1245 | 12·4 | 24·8 | 44·2 | 18·8 | 28·9 | 11·0 |
| 17 | 1·133 | 1·1335 | 13·3 | 26·6 | 46·5 | 20·0 | 30·7 | 11·7 |
| 18 | 1·142 | 1·1425 | 14·2 | 28·4 | 49·7 | 21·2 | 32·6 | 12·4 |
| 19 | 1·151 | 1·1515 | 15·1 | 30·2 | 52·5 | 22·3 | 34·4 | 13·1 |
| 20 | 1·160 | 1·1607 | 16·0 | 32·0 | 55·2 | 23·5 | 36·2 | 13·8 |
| 21 | 1·169 | 1·1705 | 16·9 | 33·8 | 57·8 | 24·6 | 38·0 | 14·5 |
| 22 | 1·179 | 1·1795 | 17·9 | 35·8 | 60·7 | 25·8 | 40·0 | 15·2 |
| 23 | 1·188 | 1·1895 | 18·8 | 37·6 | 63·3 | 26·9 | 41·7 | 15·8 |
| 24 | 1·198 | 1·1995 | 19·8 | 39·6 | 66·1 | 28·1 | 43·6 | 16·5 |
| 25 | 1·208 | 1·2095 | 20·8 | 41·6 | 68·9 | 29·3 | 45·5 | 17·2 |
| 26 | 1·218 | 1·2195 | 21·8 | 43·6 | 71·6 | 30·4 | 47·3 | 17·9 |
| 27 | 1·229 | 1·2300 | 22·9 | 45·8 | 74·5 | 31·7 | 49·4 | 18·6 |
| 28 | 1·239 | 1·2405 | 23·9 | 47·8 | 77·2 | 32·8 | 51·2 | 19·3 |
| 29 | 1·250 | 1·2515 | 25·0 | 50·0 | 79·3 | 34·0 | 53·2 | 20·0 |
| 30 | 1·261 | 1·2625 | 26·1 | 52·2 | 82·8 | 35·2 | 55·1 | 20·7 |
| 31 | 1·272 | 1·2735 | 27·2 | 54·4 | 85·5 | 36·4 | 57·0 | 21·4 |
| 32 | 1·283 | 1·2850 | 28·3 | 56·6 | 88·3 | 37·5 | 58·9 | 22·1 |
| 33 | 1·295 | 1·2960 | 29·5 | 59·0 | 91·1 | 38·8 | 60·9 | 22·8 |
| 34 | 1·306 | 1·3080 | 30·6 | 61·2 | 93·7 | 39·9 | 62·7 | 23·4 |
| 35 | 1·318 | 1·3200 | 31·8 | 63·6 | 96·5 | 41·0 | 64·7 | 24·1 |

COMPARISON OF VARIOUS HYDROMETER SCALES.—(*Continued.*)

| Degrees Baumé. | Specific Gravities. | | Degrees Densimetric 15·5 C. | Degrees Twaddell 60 Fahr. 1° = 200 (Sp. gr.—1). | Degrees Brix. Official Prussian Hydrometer 15·6° C. Sp. gr. = $\frac{400}{400-Bx^\circ}$ | Degrees Beck 12·5° C. Sp. gr. = $\frac{170}{170-Bk^\circ}$ | Degrees Brix Saccharimetric (per cent. Sugar). | Gay-Lussac (Centigrade). Sp. gr. = $\frac{100}{100-C^\circ}$ |
|---|---|---|---|---|---|---|---|---|
| | Standard adopted by U.S. Chem. Mfg. Ass. 15·5°. Sp. gr. = $\frac{145·04}{145·04-B}$ | Modulus 144·38. Custom in France. | | | | | | |
| 36 | 1·330 | 1·3320 | 33·0 | 66·0 | 99·2 | 42·2 | 66·7 | 24·8 |
| 37 | 1·342 | 1·3445 | 34·2 | 68·4 | 101·9 | 43·3 | 68·6 | 25·5 |
| 38 | 1·355 | 1·3570 | 35·5 | 71·0 | 104·7 | 44·6 | 70·7 | 26·2 |
| 39 | 1·368 | 1·3700 | 36·8 | 73·6 | 107·6 | 45·8 | 72·7 | 26·9 |
| 40 | 1·381 | 1·3830 | 38·1 | 76·2 | 110·3 | 46·9 | 74·7 | 27·6 |
| 41 | 1·394 | 1·3955 | 39·4 | 78·8 | 113·5 | 48·0 | 76·7 | 28·3 |
| 42 | 1·408 | 1·4100 | 40·8 | 81·6 | 115·9 | 49·3 | 78·8 | 28·9 |
| 43 | 1·421 | 1·4240 | 42·1 | 84·2 | 118·5 | 50·4 | 80·8 | 29·6 |
| 44 | 1·436 | 1·4380 | 43·5 | 87·0 | 121·3 | 51·5 | 82·9 | 30·3 |
| 45 | 1·450 | 1·4525 | 45·0 | 90·0 | 124·1 | 52·8 | 85·1 | 31·0 |
| 46 | 1·465 | 1·4675 | 46·5 | 93·0 | 126·7 | 53·9 | 87·2 | 31·7 |
| 47 | 1·479 | 1·4827 | 48·0 | 96·0 | 129·7 | 55·1 | 89·4 | 32·4 |
| 48 | 1·495 | 1·4980 | 49·5 | 99·0 | 132·4 | 56·3 | 91·5 | 33·1 |
| 49 | 1·510 | 1·5135 | 51·0 | 102·0 | 135·1 | 57·4 | 93·6 | 33·8 |
| 50 | 1·526 | 1·5300 | 52·6 | 105·2 | 137·9 | 58·6 | .. | 34·5 |
| 51 | 1·542 | 1·5460 | 54·2 | 108·4 | 140·6 | 59·8 | .. | 35·2 |
| 52 | 1·559 | 1·5630 | 55·9 | 111·8 | 143·4 | 61·0 | .. | 35·9 |
| 53 | 1·576 | 1·5800 | 57·6 | 115·2 | 146·2 | 62·2 | .. | 36·6 |
| 54 | 1·593 | 1·5965 | 59·3 | 118·6 | 148·9 | 63·3 | .. | 37·2 |
| 55 | 1·611 | 1·6150 | 61·1 | 122·2 | 151·7 | 64·5 | .. | 37·9 |
| 56 | 1·629 | 1·6335 | 62·9 | 125·8 | 154·5 | 65·7 | .. | 38·6 |
| 57 | 1·648 | 1·6520 | 64·8 | 129·6 | 157·3 | 66·9 | . | 39·3 |
| 58 | 1·666 | 1·6715 | 66·7 | 133·4 | 160·0 | 68·0 | .. | 40·1 |
| 59 | 1·686 | 1·6910 | 68·6 | 137·2 | 162·8 | 69·2 | .. | 40·7 |
| 60 | 1·706 | 1·7110 | 70·6 | 141·2 | 165·5 | 70·4 | .. | 41·4 |
| 61 | 1·726 | 1·7315 | 72·6 | 145·2 | 168·3 | 71·5 | .. | 42·1 |
| 62 | 1·747 | 1·7525 | 74·7 | 149·4 | 171·0 | 72·7 | .. | 42·8 |
| 63 | 1·768 | 1·7740 | 76·8 | 153·6 | 173·8 | 73·8 | .. | 43·4 |
| 64 | 1·790 | 1·7950 | 79·0 | 158·0 | 176·5 | 75·0 | .. | 44·1 |
| 65 | 1·812 | 1·8185 | 81·2 | 162·4 | 179·3 | 76·2 | .. | 44·8 |
| 66 | 1·835 | 1·8420 | 83·5 | 167·0 | 182·0 | 77·4 | .. | 45·5 |
| 67 | 1·859 | 1·8660 | 85·9 | 171·8 | 184·8 | 78·6 | .. | 46·2 |
| 68 | 1·883 | 1·8910 | 88·3 | 176·6 | 187·5 | 79·7 | .. | 46·9 |
| 69 | 1·907 | 1·9151 | 90·7 | 181·4 | 190·2 | 80·9 | .. | 47·6 |
| 70 | 1·933 | 1·9410 | 93·5 | 186·6 | 193·0 | 82·1 | .. | 48·3 |
| 72·5 | 2·000 | 2·0085 | 100·0 | 200·0 | 200·0 | 85·0 | .. | 50·0 |

## FREEZING TIMES FOR DIFFERENT TEMPERATURES AND THICKNESSES OF CAN ICE.

(*Siebert.*)

| Thickness. | | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. | 12 in. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 10° | 0·32 | 1·28 | 2·86 | 5·10 | 8·00 | 11·5 | 15·6 | 20·4 | 25·8 | 31·8 | 38·5 | 45·8 |
| ,, | 12° | 0·35 | 1·40 | 3·15 | 5·60 | 8·75 | 12·6 | 17·3 | 22·4 | 28·4 | 35·0 | 42·3 | 50·4 |
| ,, | 14° | 0·39 | 1·56 | 3·50 | 6·22 | 9·70 | 14·0 | 19·0 | 25·0 | 31·5 | 39·0 | 47·0 | 50·0 |
| ,, | 16° | 0·44 | 1·75 | 3·94 | 7·00 | 11·0 | 15·8 | 21·5 | 28·0 | 35·5 | 43·7 | 53·0 | 63·0 |
| ,, | 18° | 0·50 | 2·00 | 4·50 | 8·00 | 12·5 | 18·0 | 24·5 | 32·0 | 40·5 | 50·0 | 60·5 | 72·0 |
| ,, | 20° | 0·58 | 2·32 | 5·25 | 9·30 | 14·6 | 21·0 | 28·5 | 37·3 | 47·2 | 58·3 | 70·5 | 84·0 |
| ,, | 22° | 0·70 | 2·80 | 6·30 | 11·2 | 17·5 | 25·2 | 31·3 | 44·8 | 56·7 | 70·0 | 84·7 | 100·0 |
| ,, | 24° | 0·88 | 3·50 | 7·86 | 14·0 | 21·0 | 31·5 | 42·8 | 56·0 | 71·0 | 87·5 | 106·0 | 120·0 |

## TIME REQUIRED FOR WATER TO FREEZE IN ICE CANS.

(*The Triumph Ice Machine Company, Catalogue.*)

Cans, size, 6 in. by 12 in. by 24 in. Weight of cake, 50 lbs. Time to freeze, 20 hours.

Cans, size, 8 in. by 18 in. by 32 in. Weight of cake, 100 lbs. Time to freeze, 36 hours.

Cans, size, 8 in. by 16 in. by 40 in. Weight of cake, 150 lbs. Time to freeze, 36 hours.

Cans, size, 11 in. by 22 in. by 32 in. Weight of cake, 200 lbs. Time to freeze, 55 hours.

Cans, size, 11 in. by 22 in. by 44 in. Weight of cake, 300 lbs. Time to freeze, 60 hours.

Cans, size, 11 in. by 22 in. by 57 in. Weight of cake, 400 lbs. Time to freeze, 60 hours.

NOTE.—Temperature of bath 14 to 18 degrees Fahrenheit. As a rule, the higher the bath temperature the slower the process of freezing, but the finer and clearer the ice.

## STORING ICE.

For storing purposes ice should be clear, solid, and devoid of core. In America some persons insist that ice for storage should not be made at temperatures higher than 10° to 14° in brine tank.

The first requisite for a storage house for artificial ice, as also for natural ice, is of course the best possible insulation; other necessary points to be attended to are drainage and ventilation. The best shape for an ice storage house is square, or as nearly approaching this form

as possible, and the roof should have a good pitch. An ante-room or lobby is also desirable, as by the provision of this latter the necessity for the frequent opening of the main store is done away with.

To preserve the ice, the storage rooms as well as the ante-chambers or lobbies must be refrigerated, and the amount of the latter required may be roughly estimated, according to Prof. Siebel, at from about ten to sixteen British thermal units of refrigeration per cubic feet contents for twenty-four hours. About one foot of 2-inch pipe (or its equivalent in other size pipe) per fourteen to twenty cubic feet of space is frequently allowed, says the same gentleman, in ice storage houses for direct expansion, and about one-half to one-third more for brine circulation. The pipes should be located on the ceiling of the ice storage house.

The ventilation of an ice storage house should be carefully attended to, and ventilators fitted with suitable regulators should be provided both in the highest part of the roof and also in the gable ends. The drainage should be such as to absolutely prevent the accumulation of any moisture beneath the bed of ice. It is recommended to paint an ice store white, preferably with a mineral paint such as barytes, or patent white.

Respecting the best method to adopt for packing the ice in the store, considerable diversity of opinion seems to exist. It is well to provide a bed of from eighteen inches to two feet of cinders, as this tends to improve the drainage of the house. In one method the blocks are placed on edge and as closely packed together as possible, the blocks in each succeeding layer being placed exactly over those beneath and all breaking of joints being avoided. The ice is covered between the times of storing with dry sawdust or soft wood shavings, and the uppermost layer is invariably covered with dry sawdust or shavings.

Mr. R. Thompson, writing to the Canadian *Farming World*, says that in filling the house he puts the ice on edge, placing every alternate layer crossways, which plan, he claims, enables ice to keep better and come out easier.

Others recommend that the ice be stored with alternate ends touching, and alternately from one and a half to two

inches apart, so as to prevent the ice from freezing together. The cakes or slabs of ice should not be parallel to each other, and storage should only be made when the temperature is at or below freezing. Or, again, $\frac{1}{2}$-inch strips placed between the layers of ice in the store so as to separate the cakes or blocks top, side, and bottom, from all others in the house.

For packing the ice, sawdust, rice chaff, straw, hay—marsh or prairie hay being said to be preferable—are employed, the latter materials being the best, and rice chaff being capable of being dried and re-used. Six inches of well-packed hay should be placed between the ice and the walls, and no covering until the store is full.

A cubic foot of ice is taken to weigh 57·5 lbs. approximately at 32° Fahr. A cubic foot of water frozen at 32° will make 1·0855 cubic foot of ice, thus showing an expansion of 8·5 per cent. due to freezing. A cubic foot of pure water at 39° Fahr., its point of greatest density, weighs 62·43 lbs. Fifty cubic feet of ice, as usually stored, equals about one American or short ton of ice (2000 lbs.), or 62 cubic feet one English ton. In small ice houses, in which the ice is closely packed, a short ton of ice can be got into from 40 to 45 cubic feet.

When withdrawing ice from a store, breaking out bars for bottom and side breaking are required, and if properly skilled assistance is not available a considerable amount of the ice will in all probability be broken up and wasted.

The wastage of ice in an ice store not artificially cooled from January to July is, in the United States, at the rate of about 0·1 lb. of ice per twenty-four hours for each square foot of wall surface, or say from 5 to 10 per cent. of the ice stored during the six months.

The amount of heat that will pass through a square foot of ice one inch in thickness is put at 10 British thermal units per hour for each degree Fahrenheit difference between the respective temperatures on each side of the sheet of ice.

In handling and selling ice, the waggons should be clean and sanitary, the men in charge should avoid walking about in them with dirty boots, and blocks of ice should not be deposited and slid about on filthy pavements. These

matters are attended to in the United States, but here they are totally neglected.

In the United States the selling and delivery of ice is generally done by the coupon system, which is thus described by Prof. Siebel: "It is a system of keeping an accurate account with each customer of the delivery of and the payment for ice by means of a small book containing coupons, which in the aggregate equal 500 or 1000 or more pounds of ice taken by the customer every time ice is delivered. These books are used in the delivery of ice in like manner as mileage books or tickets are used on the railroad. A certain number of coupons are printed on each page, each coupon being separated from the others by perforation, so that they are easily detached and taken up by the driver, when ice is delivered. Such books are each supplied with a receipt or due bill, so that if the customer purchases his ice on credit, all that is necessary for the dealer to do is to have the customer sign the receipt or due bill and hand him the book containing coupons equal in the aggregate to the number of pounds of ice set forth in the receipt or due bill. The dealer then has the receipt or due bill, and the customer has the book of coupons. The only entry which the dealer has to enter against such purchaser in his books is to charge him with coupon book number, as per number on book, to the amount of 500, 1000, or more pounds of ice, as the value of the book so delivered may be. The driver then takes up the coupons as he delivers the ice from day to day."

## SECTION IV.

### INSULATION.

In addition to non-conducting qualities, a good insulating material should be non-odorous, non-hygroscopic, not liable to silt, and both vermin and fire-proof.

Perfect insulation would be attained when there was absolutely no transmission of heat through the walls of the building, which state of things is practically an impossibility. Every one should, however, endeavour to secure as near an approximation to the above as possible, and it should be remembered that poor insulation is a constant drain upon the machinery and pocket of the owner, as a very large percentage of the actual work of a refrigerating machine is that required to make up for the transfer of heat through the walls, floor, and ceiling of the cold store, resulting from defective insulation.

In the following tables the results of a number of tests as to the values of different insulating materials are given, and from these tables may be deduced sufficient information to enable an intelligent choice to be made. In Australia pumice stone is much used, and is said to give good results. In this country and the United States silicate cotton or slag-wool; cork, in slabs, bricks, and granulated; and charcoal are employed, and there is something to be said in favour of each of these materials.

When charcoal is employed it should be well dried, and packed as nearly as possible to a consistency of 11 lbs. per cubic foot. Silicate cotton or slag-wool is usually packed to a consistency of about 12 lbs. per cubic foot, one ton equalling about 187 cubic feet. Some engineers prefer, however, to use 13 lbs. per cubic foot.

An advantage possessed by granulated cork is its extreme lightness. One cubic foot weighs only $4\frac{1}{2}$ lbs., and one ton occupies about 450 cubic feet.

## Transmission of Heat through various Insulating Structures.—(*Starr, American Warehousemen's Assoc.*)

Col. I. gives B.T.U. per square foot per day per degree of difference of temperature. Col. II. gives meltage of ice in pounds per day by heat coming through 100 square feet at a difference of 40°.

| | Col. I. | Col. II |
|---|---|---|
| One ⅞-in. board, 2½-in. mineral wool, paper, one ⅞-in. board .. .. .. .. .. . .. | 3·62 | 101·0 |
| Two ⅞-in. double boards and two papers, 1-in. hair-felt | 3·318 | 93·1 |
| Two ⅞-in. boards and paper, 1-in. sheet cork, two ⅞-in. boards and paper .. .. .. .. .. | 3·30 | 92·0 |
| One ⅞-in. board, paper, 2-in. calcined pumice, paper, and ⅞-in. board .. .. .. .. . | 3·38 | 95·2 |
| One ⅞-in. board, paper, 3-in. sheet cork, paper, one ⅞-in. board .. .. .. .. . . | 2·10 | 60·0 |
| Double boards and papers, 4-in. granulated cork, double boards and paper .. .. .. .. .. | 1·70 | 48·0 |

## Results of Tests to determine the Non-Conductive Values of Different Materials.

(*H. F. Donaldson, M.I.C.E., Proceedings, Inst. C.E.*)

### Experiment No. 1.

| — | Thickness of Insulating Material. | Original Weight of Ice. | Weight after Twenty-four Hours. | Weight after Seventy-two Hours. | Loss after Seventy-two Hours. |
|---|---|---|---|---|---|
| | Inches. | Ozs. | Ozs. | Ozs. | Per cent. |
| Peat (compressed and set in Fossil Meal) .. .. | 9 | 95 | 81 | 59 | 37·89 |
| Charcoal .. .. | 11 | 96½ | 79½ | 56 | 41·97 |
| Silicate Cotton .. | 4½ | 92½ | 73½ | 40½ | 56·21 |
| Magnesia and Asbestos Fibre .. | 4½ | 93 | 73 | 40½ | 56·45 |

Note.—The author thought it undesirable to consider further compressed peat set in fossil meal, as he found by experiment its powers of absorption of moisture to be so great as to constitute in his opinion a source of danger.

## EXPERIMENT No. 2.

| — | Thickness of Insulating Material. | Original Weight of Ice. | Weight after Twenty-four Hours | Weight after Forty-eight Hours. | Weight after Ninety-six Hours. | Loss after Ninety-six Hours. |
|---|---|---|---|---|---|---|
| | Inches. | Ozs. | Ozs. | Ozs. | Ozs. | Per cent |
| Silicate Cotton | 6 | 104 | 88¾ | 76¾ | 58½ | 43·75 |
| Sawdust .. | 9 | 103½ | 86½ | 71 | 48 | 52·62 |
| Peat .. .. | 9 | 104 | 77½ | 56 | 26¼ | 74·75 |
| Charcoal .. | 9 | 104 | 88¾ | 78½ | 60½ | 41·82 |

## EXPERIMENT No. 3.

| — | Thickness of Insulating Material. | Original Weight of Ice. | Weight after Twenty-four Hours | Weight after Seventy-two Hours. | Loss after Seventy-two Hours. |
|---|---|---|---|---|---|
| | Inches. | Ozs. | Ozs. | Ozs. | Per cent. |
| Silicate Cotton .. | 9 | 92 | 83½ | 72½ | 21·19 |
| Charcoal .. .. | 11 | 92 | 82¾ | 70½ | 23·36 |

## EXPERIMENT No. 4.

| — | Thickness of Insulating Material. | Original Weight of Ice. | Weight after Twenty-four Hours. | Weight after Ninety-six Hours. | Loss after Ninety-six Hours. |
|---|---|---|---|---|---|
| | Inches. | Ozs. | Ozs. | Ozs. | Per cent. |
| Silicate Cotton (loosely packed) | 9 | 110 | 103 | 84¼ | 23·41 |
| Silicate Cotton ... | 9 | 110 | 101¾ | 80¾ | 26·59 |
| Charcoal .. .. | 11 | 110 | 100½ | 79 | 28·18 |
| Vegetable Silica .. | 11 | 110 | 101½ | 76¾ | 30·22 |
| Diatomite .. .. | 11 | 110 | 99 | 73¾ | 32·95 |

## Results of Tests to determine the Non-Conductive Values of Various Materials.

(*Dr. Wm. Wallace.*)

| Materials. | Cubic Centimetres (grammes) of water melted in 12 days. | Average c.c.'s per day. |
|---|---|---|
| Silicate Cotton .. .. .. | 9,470 | 789 |
| Flake Charcoal .. .. .. | 11,010 | 917 |
| Felt .. .. .. .. .. | 11,760 | 980 |
| Fossil Meal .. .. .. .. | 12,530 | 1,044 |
| Twig Charcoal .. .. .. | 13,590 | 1,132 |
| Plain Cork Slabs .. .. .. | 14,020 | 1,168 |
| Tarred Cork Slabs .. .. .. | 14,610 | 1,217 |
| Broken Lump Charcoal .. .. | 15,916 | 1,326 |
| Ashes .. .. .. .. .. | 23,316 | 1,943 |

Coleman's method was used in making the above tests, with walls 6 in. thick.

## Rate of Passage of Heat through Various Materials.—(*Alex. Marcet.*)

| British Thermal Units per hour per superficial foot through materials 6 in. thick. | | | | | | |
|---|---|---|---|---|---|---|
| | T = 60° | | T = 50° | | T = 40° | |
| | Dry. | Wet. | Dry. | Wet. | Dry. | Wet. |
| Silicate Cotton .. | 4·11 | 14·05 | 2·34 | 8·57 | 1·17 | 6·70 |
| Cow Hair .. .. | 4·11 | 8·80 | 2·34 | 5·30 | 1·17 | 3·50 |
| Charcoal .. .. | 4·70 | 12·30 | 2·93 | 7·50 | 1·76 | 4·40 |
| Sawdust .. .. | 6·75 | 15·60 | 4·40 | 9·60 | 2·34 | 5·50 |
| Infusorial Earth .. | 10·00 | — | 6·18 | — | 3·57 | — |
| Cork Bricks .. | 5·87 | — | 3·20 | — | 2·90 | — |

T = The Difference of Temperature (Fahr.) on the two sides of the material.

## Results of Tests on the Heat Conductivity of Different Substances

*(Various authorities.)*

(Silicate Cotton being taken at 100.)

| SUBSTANCE. | C. E. Emery, 1881. | J. J. Coleman, 1884. | W. H. Collins, 1891. | Prof. Jamieson 1894. |
|---|---|---|---|---|
| Silicate Cotton or Slag Wool .. | 100 | 100 | 100 | 100 |
| Hair-Felt or Fibrous Composition | — | 117 | 114 | 112 |
| Papier-Maché .. .. .. | — | — | 147 | 111 |
| Kieselguhr Composition .. .. | — | 136 | — | 112 |
| Sawdust .. .. .. .. | 122 | 163 | 142 | — |
| Charcoal .. .. .. .. | 132 | 140 | — | — |
| Cotton Wool .. .. .. | — | 122 | — | — |
| Sheep's Wool .. .. .. | — | 136 | — | — |
| Pine Wood (across the grain) .. | 150 | — | — | — |
| Loam .. .. .. .. | — | — | — | — |
| Gasworks Breeze or Coal Ashes .. | 240 | 230 | 299 | — |
| Asbestos .. .. .. .. | 229 | — | 179 | — |

## Table giving the Relative Heat Conductivity of Various Boiler-covering Materials.

*(The "American Engineer.")*

| | |
|---|---|
| Silicate Cotton or Mineral Wool .. .. .. | 100 |
| Hair Felt .. .. .. .. .. .. | 117 |
| Cotton Wool .. .. .. .. .. .. | 122 |
| Sheep's Wool .. .. .. .. .. .. | 136 |
| Infusorial Earth .. .. .. .. .. | 136 |
| Charcoal .. .. .. .. .. .. | 140 |
| Sawdust .. .. .. .. .. .. | 163 |
| Gasworks Breeze .. .. .. .. .. | 230 |
| Wood and air space .. .. .. .. .. | 280 |

## Results of Experiments Regarding Non Heat-conducting Properties of Various Substances.—(*Prof. J. M. Ordway.*)

| | | Coverings 1 inch thick. | Pounds of Water heated 10° F. per hour by 1 sq. foot. |
|---|---|---|---|
| | 1 | "Silicate Cotton" or "Slag Wool" .. | 13·0 |
| | 2 | Paper .. . .. .. .. | 14·0 |
| * | 3 | Cork Strips, bound on .. .. .. | 14·6 |
| | 4 | Straw Rope, wound spirally .. .. | 18·0 |
| | 5 | Loose Rice Chaff .. .. .. .. | 18·7 |
| | 6 | Blotting Paper, wound tight .. .. | 21·0 |
| | 7 | Paste of Fossil Meal and Hair .. .. | 16·7 |
| | 8 | Loose Bituminous Coal Ashes .. .. | 21·0 |
| | 9 | Paste of Fossil Meal with Asbestos .. | 22·0 |
| † | 10 | Loose Anthracite Coal Ashes .. .. | 27·0 |
| | 11 | Paste of Clay and Vegetable Fibre .. | 30·9 |
| | 12 | Dry Plaster of Paris .. .. .. | 30·9 |
| | 13 | Asbestos Paper, wound tight .. .. | 21·7 |
| | 14 | Air alone .. .. .. .. .. | 48·0 |
| | 15 | Fine Asbestos .. .. .. .. | 49·0 |
| | 16 | Sand .. .. .. .. .. .. | 62·1 |

* These substances are not well suited for covering heated surfaces—owing to their nature they soon become carbonised.

† Hard substances that, with the action of the heat, break, powder, and fall off.

N.B.—The Asbestos of 15 had smooth fibres, which could not prevent the air from moving about. Later trials with an Asbestos of exceedingly fine fibre have made a somewhat better showing, but Asbestos is really one of the poorest non-conductors. By reason of its fibrous character it may be used advantageously to hold together other incombustible substances, but the less the better.

## Non Heat-conducting Properties of Various Substances.—(*From "Engineering."*)

| Prepared Mixtures, for Covering Boilers, Pipes, &c. | Pounds of Water heated 10° Fahr. per hour, per square foot. |
|---|---|
| Slag Wool (Silicate Cotton) and Hair Paste .. | 10·0 lbs. |
| Fossil Meal and Hair Paste .. .. .. .. | 10·4 ,, |
| Paper Pulp alone .. .. .. .. .. | 14·7 ,, |
| Asbestos Fibre, wrapped tightly .. .. .. | 17·9 ,, |
| Fossil Meal and Asbestos Powder .. .. .. | 26·3 ,, |
| Coal Ashes and Clay Paste, wrapped with Straw.. | 29·9 ,, |
| Clay, Dung, and Vegetable Fibre Paste .. .. | 39·6 ,, |
| Paper Pulp, Clay and Vegetable Fibre .. .. | 44·6 ,, |

## Results of Experiments Regarding Non Heat-conducting Properties of Various Substances.

(*Walter Jones, "Heating by Hot Water."*)

| Frame Filled with | Left for | Highest Temp. Registered. |
|---|---|---|
| Leroy's Boiler-covering Composition .. | 3 hours | 94° |
| Asbestos Powder .. .. .. | 4 " | 86° |
| Hair Felt .. .. .. .. .. | 9 " | 77° |
| Silicate Cotton .. .. .. .. | 9 " | 76° |

## Heat in Units transmitted per Square Foot per Hour through Various Substances.

(*Peclet.*)

| Materials. | Units of heat transmitted. | Materials. | Units of heat transmitted. |
|---|---|---|---|
| Gold . . . . | 625 | Guttapercha . . | 1·37 |
| Platinum . . . | 600 | India-rubber . . | 1·36 |
| Silver . . . . | 595 | Brickdust, sifted . . | 1·33 |
| Copper . . . | 520 | Coke, in powder . . | 1·29 |
| Iron . . . . | 230 | Iron filings . . . | 1·26 |
| Zinc . . . . | 225 | Cork . . . . | 1·15 |
| Tin . . . . | 178 | Chalk, in powder . | 0·86 |
| Lead . . . . | 113 | Charcoal (wood) in powder . . . . | 0·63 |
| Marble . . . | 24 | Straw, chopped . . | 0·56 |
| Stone . . . . | 14 | Coal, powder sifted . | 0·54 |
| Glass . . . . | 6·6 | Wood ashes . . | 0·53 |
| Terra-cotta . . . | 4·8 | Mahogany dust . . | 0·52 |
| Brickwork . . . | 4·8 | Canvas, hempen new . | 0·41 |
| Plaster . . . | 3·8 | Calico, new . . | 0·40 |
| Sand . . . . | 2·17 | Writing-paper, white . | 0·34 |
| Oak, against the grain or fibre . . . | 1·7 | Cotton and sheep's wool | 0·32 |
| Walnut, with the grain or fibre . . . | 1·4 | Eiderdown . . . | 0·31 |
| Fir, with the grain or fibre . . . | 1·37 | Blotting-paper, grey . | 0·26 |

Relative and Absolute Thermal Conductivity of Substances used as Lagging for Steam Boilers.—(*Professor Jamieson.*)

Results of the Tests.

| Name of Material. | Weight of Sample (including Tin). | | Total fall of Temperature in 120 minutes. | Thermal Conductivity in Absolute Measure. | Conductivity as Compared with Dry Still Air. |
|---|---|---|---|---|---|
| | lbs. | oz. | Deg. Cent. | | |
| Dry air . . . . . | — | | 6·0 | 0·0000558 | 1·00 |
| Fossil meal composition . | 7 | 2 | 21·5 | 0·0002689 | 4·82 |
| Cement with hair felt* . | 5 | 15 | 30·0 | 0·0003613 | 6·47 |
| Silicate cotton,† or slag wool . . . . . | — | | 29·0 | 0·0003875 | 6·95 |
| Kieselguhr‡ composition | 7 | 13 | 29·0 | 0·0004336 | 7·77 |
| Papier maché composition§ | 7 | 6 | 35·5 | 0·0004424 | 7·93 |
| Fibrous composition (flax, hemp, cow-hair, and clay) | 9 | 9 | 34·5 | 0·0004550 | 7·98 |
| Papier maché composition‖ | 8 | 12 | 37·5 | 0·0005019 | 8·99 |

* The outside diameter of this sample was about ¼ in. smaller than the inside diameter of the middle tin-case or vessel, and it had consequently a slight advantage over the other samples in having a thin layer of air between its outer surface and the latter.

† The silicate cotton was pressed together tightly, and thus its conductivity appears greater than would have been the case had it been more loosely packed.

‡ The Kieselguhr employed consisted on the average of Silica 83·8, Magnesia 0·7, Lime 0·8, Alumina 1·0, Peroxide of Iron 2·1, Organic Matter 4·5, Moisture and Loss, 7·1. It was employed in conjunction with 10 per cent. of binding material, viz., fibre and mucilaginous extract of several vegetable matters.

§ Papier maché composition, consisting of paper pulp mixed with clay and carbon, together with hair and fragments of hemp rope.

‖ A lighter modification of above.

The quantity of heat in units, transmitted through one square foot of plate per hour, may be found thus: Subtract

the temperature of the cooler side from that of the hotter side of the plate, then multiply the result by the number in the table on p. 121 corresponding to the material used, and divide the product by the thickness of plate in inches. Thus an iron plate 2 in. thick, having a temperature of 60° on one side and 80° on the other, will transmit $80 - 60 \times \frac{230}{2} = 2300$ units of heat per square foot per hour.

### Heat-conducting Power of Various Substances, Slate being 1000.—(*Molesworth.*)

| | | | |
|---|---|---|---|
| Slate | 1,000 | Chalk | 564 |
| Lead | 5,210 | Asphalt | 451 |
| Flagstone | 1,110 | Oak | 336 |
| Portland stone | 750 | Lath and plaster | 255 |
| Brick | 600 to 730 | Cement | 200 |
| Fire-brick | 620 | | |

### Tests regarding Conductivities of Asbestos and Kieselguhr.—(*J. G. Dobbie.*)

#### Results of Tests.

| | Asbestos. | Kieselguhr Composition. |
|---|---|---|
| | Water Condensed in Inches. | Water Condensed in Inches. |
| After 15 minutes | $4\frac{1}{4}$ | $2\frac{1}{2}$ |
| ,, 30 ,, | $3\frac{3}{4}$ | $2\frac{3}{8}$ |
| ,, 45 ,, | $3\frac{3}{8}$ | $2\frac{1}{4}$ |
| ,, 60 ,, | $3\frac{3}{8}$ | $2\frac{1}{8}$ |
| Totals in one hour | $14\frac{3}{4}$ | $9\frac{1}{4}$ |

RESULTS OF DIFFERENT EXPERIMENTS ON THE HEAT CONDUCTIVITIES OF VARIOUS SUBSTANCES.—(*W. H. Collins.*)

(*Silicate cotton being taken as* 100.)

| Substance. | C. E. Emery. 1881. | J. J. Coleman. 1884. | W. H. Collins. 1891. | Prof. Jamieson. 1894. |
|---|---|---|---|---|
| Fossil meal composition | .. | .. | .. | 70 |
| Cement with hair-felt | 83 | .. | .. | 93 |
| Silicate cotton or slag wool | 100 | 100 | 100 | 100 |
| Hair-felt or fibrous composition | .. | 117 | 114 | 112 |
| Papier-maché | .. | .. | 147 | 111 |
| Kieselguhr composition | .. | 136 | .. | 112 |
| Sawdust | 122 | 163 | 142 | .. |
| Charcoal | 132 | 140 | .. | .. |
| Cotton wool | .. | 122 | .. | .. |
| Sheeps' wool | .. | 136 | .. | .. |
| Pine wood (across the grain) | 150 | .. | .. | .. |
| Loam | .. | .. | .. | .. |
| Gasworks breeze or coal ashes | 240 | 230 | 299 | .. |
| Asbestos | 229 | .. | 179 | .. |

## EXPERIMENTS BY T. B. LIGHTFOOT AND G. A. BECKS.

### EXPERIMENT NO. 1.

Duration of experiment, 48 hours. Average temperature of room or chamber, 90° F.

A piece of ice 23 lbs. in weight was placed in a zinc box 12 in. cube, and covered with 2 in. silicate cotton, this latter being provided with an outer cover, also of zinc. When the ice was taken out it weighed 10½ lbs., showing a loss of 12½ lbs.

12½ lbs. × 142 (latent heat of ice) = 1775 thermal units passed through in 48 hours. $\frac{1775}{48} = 36{\cdot}979166$ thermal units passed through in 1 hour.

Difference in temperature between inner box and outer air = 58° F. $\frac{36{\cdot}9}{58} = 0{\cdot}63$ thermal unit transmitted per hour per degree difference in temperature. Area of zinc boxes: inner box, 6 sq. ft.; outer, 10·6 sq. ft.; mean, 8·1 sq. ft.

Thermal units transmitted through the three areas—

$$\therefore \frac{0{\cdot}63}{6} = 0{\cdot}105,\ \frac{0{\cdot}63}{8{\cdot}1} = 0{\cdot}07,\ \frac{0{\cdot}63}{10{\cdot}6} = 0{\cdot}059$$

which being multiplied by 2 for the thickness of cotton, gives thermal units per hour, per degree difference in temperature, per square foot, per inch of thickness, as follows: 0·210 inner tin, 0·118 outer tin, 0·14 mean.

### Experiment No. 2.

Duration, 48 hours. Average temperature of room, 90° F.

A piece of ice 26 lbs. in weight, covered with 6 in. of charcoal. When taken out it weighed 7½ lbs., showing a loss of 18½ lbs. $18{\cdot}5 \times 142 = 2627$ thermal units in 48 hours. $\frac{2627}{48} = 54{\cdot}72$ thermal units per hour. $\frac{54{\cdot}72}{58} = 0{\cdot}94$ thermal units per hour, per degree difference in temperature between inner box and outer air. Area of tins. inner box, 6 sq. ft.; outer, 24 sq. ft.; mean, 13·5 sq. ft.

The number of thermal units transmitted per hour, per degree, per square foot—

$$\frac{0{\cdot}94}{6} = 0{\cdot}15,\ \frac{0{\cdot}94}{13{\cdot}5} = 0{\cdot}069,\ \frac{0{\cdot}94}{24} = 0{\cdot}039$$

which being multiplied by 6 for the thickness of charcoal, gives thermal units transmitted per hour, per degree, per square foot, per inch of thickness; 0·90 inner tin, 0·234 outer tin, 4·14 mean.

### Formula for ascertaining Units of Refrigeration (R) required in 24 Hours, to carry off Heat radiated through sq. ft. ($f$) of Wall, Floor, and Ceiling.

$$R = fn(t - t_1)HU$$

HU = heat units of 772 ft. lbs., $t$ = internal temperature, $t_1$ = external temperature, and $n$ = heat units transmitted per 24 hours per sq. ft. of surface for difference of 1° Fahr. between internal and external temperature.

TRANSMISSION OF HEAT THROUGH VARIOUS INSULATING STRUCTURES.—(*Starr, American Warehousemen's Assoc.*)

| Insulating Structures. | B. T. U. per sq. ft per day per deg. of difference of temperature. | Meltage of ice in lbs. per day by heat coming through 100 sq. ft. at a difference of 40°. |
|---|---|---|
| ⅝-in. oak, paper, 1-in. lampblack ⅞-in. pine (ordinary Stock family refrigerator) .. | 5·7 | 160·7 |
| ⅞-in. board, 1-in. pitch, ⅞-in. board .. | 4·90 | 138·0 |
| Four ⅞-in. spruce boards, two papers, solid, no air-space .. .. .. .. | 4·28 | 120·0 |
| Two double boards and paper (four ⅞-in. boards), and one air-space .. .. | 3·71 | 105·0 |
| ⅞-in. board, 2-in. pitch, ⅞-in. board .. | 4·25 | 119·7 |
| ⅞-in. board, 2½-in. mineral wool, paper, ⅞-in. board .. .. . .. | 3·62 | 101 9 |
| Two ⅞-in. double boards, and two papers, 1-in. hair felt .. .. .. .. | 3·318 | 93·4 |
| Two ⅞-boards and paper, 1-in. sheet cork, two ⅞-in. boards and paper .. .. | 3·30 | 92·9 |
| ⅞-in. board, paper, 2-in. calcined pumice, paper, and ⅞-in. board .. .. .. | 3·38 | 95·2 |
| Four double ⅞-in. boards with paper between (eight boards), and three 8-in. air-spaces | 2·7 | 76·0 |
| Hair quilt insulator, four boards, four quilts hair .. .. .. .. .. | 2·517 | 70·9 |
| 7-in. board, 6-in. pat. silicated straw-board, air-cell finished inside with thin layer of patent cement .. .. .. .. | 2·48 | 69·8 |
| ⅞-in. board, paper, 3-in. sheet cork, paper, ⅞-in. board.. .. .. .. .. | 2·10 | 60·0 |
| Two ⅞-in. boards and paper, 8-in. mill shavings and paper, two ⅞-in. boards and paper .. .. .. .. .. | 1·35 | 38·3 |
| Same, slightly moist .. .. .. | 1·80 | 50·7 |
| Same, damp .. .. .. .. .. | 2·10 | 60·0 |
| Double boards and paper, 1-in. air, 4-in. sheet cork, paper, ⅞-in. board .. .. | 1·20 | 33·6 |
| Same, with 5-in. sheet cork .. .. | 0·90 | 25·3 |
| ⅞-in. board, paper, 1-in. mineral wool, paper, ⅞-in. board .. .. .. .. | 4·6 | 130·0 |
| Double boards and papers, 4-in. granulated cork, double boards and paper .. .. | 1·7 | 48·0 |

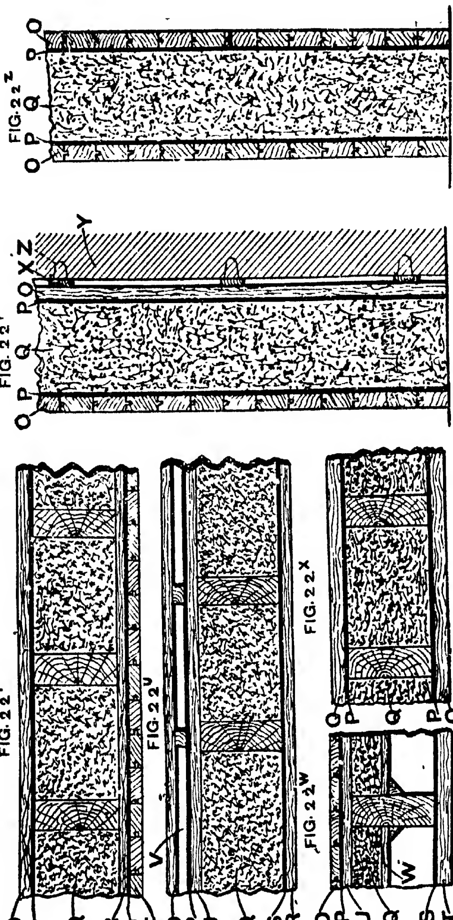
### VALUE OF AIR AS AN INSULATING MATERIAL.

Air forms an excellent insulating material when so confined as to be devoid of all movement. To prevent motion, however, it is not sufficient to merely provide a dead air-space, imprisoning the air between two walls, as under such conditions it will move about or circulate in the empty space or cavity, the direction of its motion taking place from the outside or external wall, the air contiguous to which becomes lighter owing to the rise in temperature, and rises whilst the cold air descends and takes its place, and heat will thus be constantly transmitted from the exterior to the cold chamber by convection. It is to the capacity possessed by materials such as slag wool for imprisoning between its fibres very considerable volumes of air, and retaining same in a stagnant condition that this material chiefly owes its efficiency as a non-conductor.

### EXAMPLES OF INSULATION WITH SILICATE COTTON.

The following diagrams show simple methods of insulating floors, walls, and partitions with slag wool or silicate cotton). Fig. $22^T$ is an insulated floor, O, R, and T being 1-in. grooved and tongued boarding, P and S insulating paper, and Q silicate cotton. Fig. $22^U$ consists of tongued and grooved boarding O, U, and R, air space V, layer of insulating paper P and S, and silicate cotton Q. Fig. $22^W$, 1-in. tongued and grooved boarding O and T, layers of insulating paper P and S, rough boarding W laid on fillets of wood, and loose silicate cotton Q. Fig. $22^X$, boarding O, O, layers of insulating paper P, P, and loose silicate cotton Q packed between the joists. Fig. $22^Y$ is an example of wall insulation, O, O indicating 1-in. boarding, P, P layers of insulating paper, Q loose silicate cotton, X fillets, and Z plugging sunk in the wall V of the cold room. Fig. $22^Z$ shows a form of insulated partition in which O, O represent 1-in. boarding, P, P layers of insulating paper, and Q loose silicate cotton.

It is recommended by a well-known firm of manufacturers of silicate cotton, in the case of divisional partitions, to support the insulating material on each side by galvanized wire netting 1-in. mesh, 19 gauge. This netting is claimed to render the partition virtually fireproof, as it serves to support the silicate cotton or slag wool should the match-boarding be burnt away.




FIGS. $22^{T}$, $22^{U}$, $22^{W}$, $22^{X}$, $22^{Y}$, and $22^{Z}$.—Examples of Insulation with silicate cotton or slag wool.

### Walls for Cold Stores.

The following materials and dimensions have been recommended for walls of cold chambers:—

14 in. brick wall, $3\frac{1}{2}$ in. air space, 9 in. brick wall, 1 in. layer of cement, 1 in. layer of pitch, 2 in. by 3 in. studding, layer of tar paper, 1 in. tongued and grooved boarding, 2 in. by 4 in. studding, 1 in. tongued and grooved board, layer of tar paper, and, finally, 1 in. tongued and grooved boarding, the total thickness of these layers or skins being 3 ft. 3 in.

36 in. brick wall, 1 in. layer of pitch, 1 in. sheathing, 4 in. air space, 2 in. by 4 in. studding, 1 in. sheathing, 3 in. layer of mineral or slag-wool, 2 in. by 4 in. studding, and, finally, 1 in. sheathing; total thickness, 4 ft. 7 in.

14 in. brick wall, 4 in. pitch and ashes, 4 in. brick wall, 4 in. air space, 14 in. brick wall; total thickness, 3 ft. 4 in.

14 in. brick wall, 6 in. air space, double thickness of 1 in. tongued and grooved boards, with a layer of waterproof paper between them, 2 in. layer of the best quality hair felt, second double thickness of 1 in. tongued and grooved boards, with a similar layer of paper between them; total thickness, 2 ft. 2 in.

14 in. brick wall, 8 in. layer of sawdust, double thickness of 1 in. tongued and grooved boards, with a layer of tarred waterproof paper between them, 2 in. layer of hair felt, second double thickness of 1 in. tongued and grooved boards, with a similar layer of paper between them; total thickness, 2 ft. $4\frac{1}{2}$ in.

Brick wall, 3 in. scratched hollow tiles, 4 in. silicate cotton or slag-wool, 3 in. scratched hollow tiles, and layer of cement plaster.

Brick wall, 1 in. air spaces between fillets or strips, 1 in. tongued and grooved boarding, two layers of insulating paper 1 in. tongued and grooved boarding, 2 in. by 4 in. studs, 16 in. apart, spaces filled in with silicate cotton, 1 in. tongued and grooved boarding, two layers of insulating paper, air spaces between fillets, or strips 1 in. by 2 in. spaced 16 in. apart from centres, 1 in. tongued and grooved boarding, two layers of insulating paper, and 1 in. tongued and grooved boarding.

Brick or stone wall, well coated on inside with pitch or asphaltum, 2 in. by 3 in. studding, 24 in. centres spaces between filled in with silicate cotton, ¾ in. rough tongued and grooved boarding, two layers waterproof insulating paper, ¾ in. rough tongued and grooved boarding, 2 in. by 3 in. studding 24 in. centres in spaces between, ¾ in. rough tongued and grooved boarding, two layers of waterproof insulating paper, ¾ in. rough tongued and grooved boarding, 2 in. by 3 in. studding, 24 in. centres spaces between filled in with silicate cotton, ¾ in. rough tongued and grooved boarding, two layers of waterproof insulating paper, and ¾ in. tongued and grooved match-boarding. Paper to be laid one-half lap and cemented at all joints.

Brick wall 2 in. air space, 2 in. thicknesses of tongued and grooved boards with three layers of paper between, 2 in. air space, 2 in. thicknesses of tongued and grooved boards with three layers of paper between, 2 in. air space and 2 in. thicknesses of tongued and grooved boards with three layers of paper between.

Brick wall well coated with pitch, 2 in. air space, 2 in. thicknesses of tongued and grooved boards with three layers of paper between, 2 in. space filled with slag-wool or cork, 2 in. thicknesses of tongued and grooved boards, with three layers of paper between, 2 in. space filled with slag-wool or cork, 2 in. thicknesses of tongued and grooved boards with three layers of paper between. Shelving should be fixed horizontally in the spaces packed with slag-wool or cork at about 16 in. apart.

Brick wall, 1 in. air space, ¾ in. match-boarding, 9 in. slag-wool or silicate cotton, layer of insulating paper, and ¾ in. match-boarding.

Brick wall, 1 in. air space, 6 in. slag-wool or silicate cotton, 1 in. silicate of cotton slab, layer of insulating paper, ½ in. air space, and ¾ in. match-boarding.

Brick wall, 1 in. air space, 1 in. silicate of cotton slab, 4 in. silicate of cotton, 1 in. silicate of cotton slab, ½ in. air space, and ¾ in. match-boarding.

Brick wall well coated with pitch, 2 in. air space, ⅞ in. tongued and grooved boarding, two layers of paper, ⅞ in. tongued and grooved boarding, 4 in. slag-wool or silicate cotton, ⅞ in. tongued and grooved boarding, two layers of

paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

Brick wall, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

Brick wall, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, one layer of paper, 4 in. slag-wool or silicate cotton, $\frac{7}{8}$ in. tongued and grooved boarding, one layer of paper, 4 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

Brick wall, layer of pitch, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, one layer of paper, 3 in. cork dust, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

Brick wall, $2\frac{1}{2}$ in. air space ventilated by air-bricks every 5 feet in all directions, 1 in. tongued and grooved boarding, layer of insulating paper, 1 in. tongued and grooved boarding, 12 in. charcoal supported by horizontal shelving 28 in. centres apart, 1 in. tongued and grooved boarding, two thicknesses of brown paper, and 1 in. tongued and grooved boarding.

Wall of cold storage room when made of wood: 2 in. thicknesses of tongued and grooved boarding with three layers of paper between, 2 in. air space, 2 in. thicknesses of tongued and grooved boarding with three layers of paper between, 2 in. air space, 2 in. thicknesses of tongued and grooved boarding with three layers of paper between, 2 in. air space, 2 in. thicknesses of tongued and grooved boarding with three layers of paper between, 8 in. slag-wool or silicate cotton, and 1 in. tongued and grooved boarding.

2 in. boards, $5\frac{1}{2}$ in. by 3 in. uprights, spaces between filled with carefully dried wood charcoal, $1\frac{1}{4}$ in. boarding, layer of insulating paper, and $1\frac{1}{4}$ in. boarding.

Outside siding, two layers of insulating paper, 1 in. tongued and grooved boarding, 2 in. by 6 in. studdings, 16 in. apart from centres, 1 in. tongued and grooved boarding,

two layers of insulating paper, 1 in. tongued and grooved boarding, 2 in. by 4 in. studding 16 in. apart from centres, spaces filled in with silicate cotton, 1 in. tongued and grooved boarding, two layers of insulating paper, 2 in. by 2 in. fillets or strips 16 in. apart from centres, 1 in. tongued and grooved boarding, two layers of insulating paper, and 1 in. tongued and grooved boarding.

## Divisional Partitions for Cold Stores.

Tongued and grooved match-boarding, wire netting, 6 in. silicate of cotton or slag-wool, wire netting, tongued and grooved match-boarding. The object of the netting is to render the partition fire-proof by supporting the silicate of cotton after the match-boarding might have burnt away.

$\frac{3}{4}$ in. match-boarding, $\frac{1}{2}$ in. air space, 1 in. silicate cotton slab, 4 in. of silicate of cotton or slag-wool, 1 in. silicate of cotton slab, $\frac{1}{2}$ in. air space, and 1 in. silicate of cotton slab.

2 in. tongued and grooved boarding, with three layers of paper between, 2 in. silicate of cotton or cork, 2 in. tongued and grooved boarding with three layers of paper between, 2 in. silicate of cotton or cork, 2 in. tongued and grooved boarding with three layers of paper between.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 4 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 6 in. silicate of cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, 2 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space, $\frac{7}{8}$ in.

tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 8 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 4 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

$\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. hair felt, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

## Flooring for Cold Stores.

2 in. flooring, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space between fillets or scantlings, $\frac{7}{8}$ in. tongued and grooved boarding, 12 in. joists, spaces between packed with silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space between fillets and scantlings, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and $\frac{7}{8}$ in. tongued and grooved boarding.

2 in. cement, 3 in. concrete, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, 2 in. flooring, 4 in. silicate cotton between fillets or scantlings, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, and 2 in. flooring boards on fillets or scantlings set in concrete.

2 in. asphalte, $\frac{7}{8}$ in. tongued and grooved boarding, two layers of paper, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space between scantlings, $\frac{7}{8}$ in. tongued and grooved boarding, 3 in. silicate cotton or slag-wool between fillets or scantlings, $\frac{7}{8}$ in. tongued and grooved boarding, 2 in. air space between fillets or scantlings, concrete.

1 in. asphalte, 2 in. concrete, $\frac{1}{2}$ in. pitch, 2 in. concrete, brick arches.

$1\frac{1}{4}$ in. tongued and grooved flooring, layer of insulating

paper, 2 in. by 9 in. joists, 12 in. centres apart, spaces filled with silicate cotton or slag-wool, wire netting, layer of insulating paper, $\frac{3}{4}$ in. match-boarding on 2 in. by 2 in. fillets or scantlings air spaces between, existing wooden or concrete flooring. The wire netting secured to the under side of the joists serves to retain the silicate cotton in case of fire.

1 in. tongued and grooved boarding, three layers of insulating paper, 1 in. tongued and grooved boarding, 2 in. by 9 in. joists, spaces between filled in with silicate cotton or cork, 1 in. tongued and grooved boarding, three layers of insulating paper, and 1 in. tongued and grooved boarding.

$1\frac{1}{4}$ in. tongued and grooved flooring, layer of insulating paper, 2 in. by 9 in. joists, 12 in. centres apart, spaces between filled in with silicate cotton or slag-wool, 1 in. silicate cotton slab on $\frac{1}{2}$ in. by 2 in. fillets air spaces between, and $\frac{3}{4}$ in. match-boarding. The 1 in. silicate of cotton slab is nailed on the under side of joists and is claimed to render the floor fire-proof, and to prevent radiation through the joists.

2 in. matched flooring, two layers of insulating paper, 1 in. matched sheathing, 4 in. by 4 in. sleepers 16 in. apart from centres, spaces between filled in with silicate cotton, double 1 in. matched sheathing with twelve layers of paper between, and 4 in. by 4 in. sleepers 16 in. apart from centres imbedded in 12 in. of dry underfilling.

Ground, concrete, layer of asphalte, 1 in. tongued and grooved match-boarding well tarred, two layers of stout brown paper, 1 in. tongued and grooved match-boarding, floor joists 3 in. by 11 in. spaced 21 in. apart, binder joists 11 in. by 4 in., bearing edges of floor joists protected by strips of hair felt $\frac{1}{4}$ in. thick and spaces between joists filled in with flake charcoal, and $1\frac{1}{4}$ in. tongued and grooved flooring boards.

As a further example of methods that have been actually successfully employed for insulation, it will be interesting to know that the cold storage chambers built at the St. Katherine Dock, London, were constructed as follows:—

On the concrete floor of the vault, as it stood originally, a covering of rough boards $1\frac{1}{4}$ in. in thickness were laid

longitudinally. On this layer of boards were then placed transversely, bearers formed of joists 4½ in. in depth by 3 in. in width, and spaced 21 in. apart. These bearers supported the floor of the storage chamber, which consisted of 2½ in. battens tongued and grooved. The 4½ in. wide space or clearance between this floor and the layer or covering of rough boards upon the lower concrete floor was filled with well-dried wood charcoal.

### Flooring for Ice Houses.

Floor to incline 3 in. towards central drain, and cross channelled fillets or scantlings on 1½ in. flooring, 2 in. cement, 6 in. concrete, ground.

1 in. tongued and grooved match-boarding, three layers of paper, 1 in. tongued and grooved match-boarding (to incline 3 in. towards central drain) on fillets or scantlings, air spaces between, 1 in. tongued and grooved match-boarding, three layers of paper, 1 in. tongued and grooved match-boarding, 2 in. by 9 in. joists spaces between filled with 4 in. silicate of cotton or slag-wool kept in position by ¾ in. boards secured by cleats to joists.

### Ceilings for Cold Stores and Ice Houses.

1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, 2 in. air spaces between strips or fillets, 1 in. tongued and grooved boarding, three layers of insulating paper, 1 in. tongued and grooved boarding, joists spaces between filled with silicate cotton or cork, 1 in. tongued and grooved match-boarding, three layers of insulating paper, and 1 in. tongued and grooved match-boarding.

Insulated flooring, joists, ⅞ in. tongued and grooved match-boarding, two layers of insulating paper, ⅞ in. tongued and grooved match-boarding, 2 in. spaces between strips or fillets filled in with silicate cotton or cork, ⅞ in. tongued and grooved match-boarding, three layers of insulating paper, and ⅞ in. tongued and grooved match-boarding.

1 in. tongued and grooved boarding, two thicknesses of

brown paper, 1 in. tongued and grooved boarding, joists with spaces between packed with silicate cotton, 1 in. tongued and grooved boarding, Willesden paper, and 1 in. tongued and grooved boarding.

Concrete floor, 3 in. tiles, 6 in. dry underfilling, double space hollow tile arches and layer of cement plaster.

Double 1 in. floor with two layers of insulating paper between, 2 in. by 2 in. strips or fillets 16 in. apart from centres, spaces filled in with silicate cotton, two layers of insulating paper, 1 in. tongued and grooved match-boarding, 2 in. by 2 in. strips 16 in. apart, spaces filled in with silicate cotton, two layers of insulating paper, 1 in. tongued and grooved match-boarding, joists and double 1 in. flooring with two layers of insulating paper between.

### Door Insulation.

1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, 2 in. by 1 in. fillets or strips, with spaces between filled in with silicate cotton or cork, 1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, 2 in. by 1 in. fillets or strips, spaces between filled in with silicate cotton or cork. 1 in. tongued and grooved match-boarding, three layers of insulating paper, and 1 in. tongued and grooved match-boarding.

1 in. tongued and grooved match-boarding, two layers of insulating paper, 1 in. tongued and grooved match-boarding, 12 in. space filled in with silicate cotton, 1 in. tongued and grooved match-boarding, two layers of insulating paper, and 1 in. tongued and grooved match-boarding.

### Window Insulation.

Windows are better dispensed with in cold stores and artificial light resorted to; where present, three sashes spaced a few inches apart and glazed at both sides should be used.

### Tank Insulation.

Tank sides: 4 in. air space between studding, 1 in. tongued and grooved match-boarding, three layers of

insulating paper, 1 in. tongued and grooved match-boarding, 4 in. space filled with cork, 1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, 2 in. air space, 1 in. tongued and grooved match-boarding, three layers of insulating paper, and 1 in. tongued and grooved match-boarding. Bottom: 1 in. space between strips, fillets or studding, well tarred before tank is placed in position, 1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, 1 in. air space between strips, fillets or studding, 1 in. tongued and grooved match-boarding, three layers of insulating paper, 1 in. tongued and grooved match-boarding, and 2 in. by 9 in. joists on concrete or ground spaces between filled with cinders.

Tank: 2 in. air space between fillets, $\frac{7}{8}$ in. tongued and grooved match-boarding, two layers of insulating paper, $\frac{7}{8}$ in. tongued and grooved match-boarding, 4 in. silicate cotton or slag-wool, $\frac{7}{8}$ in. tongued and grooved match-boarding, two layers of insulating paper, and $\frac{7}{8}$ in. tongued and grooved match-boarding.

Tank: 2 in. air space between studding, layer of insulating paper, 2 in. flooring, two layers of insulating paper, $\frac{7}{8}$ in. tongued and grooved boarding, joists, spaces between filled with charcoal for three-quarters depth, $\frac{7}{8}$ in. tongued and grooved match-boarding, two layers of insulating paper, $\frac{7}{8}$ in. tongued and grooved match-boarding, ground or concrete.

### Example of Insulation used Abroad.

Masonry Om. 44 (17·3 in.) in thickness covered with squares of cork Om. 15 (5·9 in.) in thickness, over which is placed a layer of cement. Squares of plate glass are also used. Ceilings in armoured concrete with hollow bricks, which retain thin layers of air in their cavities. Interior insulation consists of a layer of small charcoal especially made for the purpose Om. 20 (7·8 in.) in thickness, the inner walls being coated with inodorous resin. Floor insulation consists of squares of cork Om. 14 (5·5 in.) in thickness between the crossbeams, covered with a layer of cork Om. 03 (1·18 in.) in thickness.

## SECTION V.

## TESTING AND MANAGEMENT OF REFRIGERATING MACHINERY.

### TESTING.

THE testing of a refrigerating plant is carried out for the purpose of ascertaining what it is capable of performing under comparable normal conditions, and as to the amount of refrigeration produced in relation with the expenditure of work, and the coal consumption.

To determine the efficiency of an installation on the compression system, the following instruments and fittings are required, viz.: An indicator, so that diagrams can be taken from the compressor; stroke counters, to enable the number of strokes made by the steam-engine and brine pumps to be ascertained; and mercury wells to admit of the temperature being obtained at various points throughout the system.

In making a test it is desirable that it should last at the very least for fully 12 hours, and it is better to carry it on for 24 hours. The number of readings which it is desirable should be taken from the various instruments will vary in accordance with whether or not the work is steady or otherwise, and the person carrying out the test will have, of course, to use his own judgment on this head. Where artificial ice is made, for example, twice an hour will be sufficient, whilst on the other hand, four or more readings per hour should be taken in cases where the variation in the temperature of the materials to be cooled is wide. Indicator diagrams should be taken from both the steam-engine cylinder and the compressor cylinder every two hours.

A mercury well, for an horizontal pipe, when the latter is of sufficient dimensions, consists usually in a short piece of tubing closed at its lower end, and fitted into the pipe by means of a suitable bushing. It is filled about three parts full of mercury, and the thermometer, which should have an elongated cyclindrical bulb, is held in position therein by means of a perforated cork. For vertical pipes, or pipes of very small dimensions, where this arrangement would be impracticable, the well is generally formed by means of a wooden or other block, one side of which is shaped to the outline of the pipe to which it is to be applied, and has a suitable recess formed therein. This block is firmly secured against the pipe by metal strips in such a manner that a portion of the wall of the well will be formed by the pipe, the latter being scraped perfectly clean at that part. The joint between the block and the pipe must be made perfectly tight, which can easily be effected by means of a little white-lead paint, there being no pressure, and the whole should be surrounded by a thick layer of non-conducting composition, through which the stem of the thermometer is permitted to project.

The points in the system where it is desirable to locate the mercury wells are: The suction pipe just at its connection with the compressor; the discharge pipe, as close as possible to its connection with the compressor; the ammonia discharge pipe from the condenser, as near the latter as practicable. Where a brine circulation is employed: The pipe or manifold supplying the various coils or sets of pipes in the refrigerator; the discharge pipe of the refrigerator; the brine discharge pipe, at the point where it connects to the refrigerator; and the brine return pipe in proximity to where it connects with the refrigerator.

### Interpretation of Compressor Diagram.

The interpretation of a compressor diagram with respect to the working, valves, defects, etc., of the latter are given as follows by Hans Lorenz, in "Neuere Kuehlmaschinen," Muenchen and Leipzig, 1899.

Assuming all the parts of the machine to be in good order, then the diagram will have the general appearance

shown in Fig. 23. The suction line S is only slightly below the suction pressure line V, and the pressure line D is only slightly above the condenser pressure K. Small projections at the pressure and suction line indicate the work required to open the compressor valves, and the effect of clearance is shown by the curve R, which latter cuts the back pressure line after the piston has commenced to perform its return or back stroke, and consequently reduces the suction volume to that amount. It can also be seen from this diagram that the vapours are taken in by the compressor, not at the back pressure, but at what may be called the suction pressure, which is somewhat lower. This is the reason that the compression curve C does not intersect the back pressure line until after the piston has changed its direction of movement. The theoretical volume of the compressor, as indicated by the line V, is consequently reduced in practical working for vapours possessing a certain tension.

In Fig. 24 is shown a diagram taken from a compressor having an excessive amount of clearance. In this case, it will be seen, the back expansion line R passes through a flat course, and thereby reduces the useful volume of the compressor.

Fig. 25 is a diagram which indicates the binding of the pressure valve, which may be due to an inclined position of the guide rod of the valve. This deficiency also frequently causes a delay in the opening of the pressure valves, a state of things indicated by a too great projection in the pressure line. As soon as the valve is once opened the pressure line pursues its normal course until the piston commences its return stroke, when the defect is again manifested in the back pressure line, as mentioned.

Fig. 26 shows a diagram indicating too great a resistance in the pressure and suction pipes respectively, when the valves are over-weighted. In this case the pressure and suction line are at a comparatively great distance from the condenser pressure line and the back pressure line. The remedy for this is to replace the valve springs by weaker ones; and should there be then no marked effect, then the pipe-lines and shutting-off valves should be inspected, and, if found necessary, cleaned.

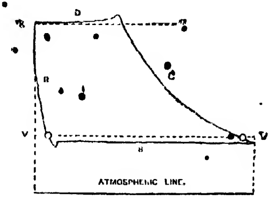



FIG. 23.—Diagram from Compressor with all parts in good order.

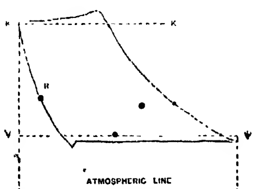



FIG. 24.—Diagram from Compressor with excessive amount of clearance.

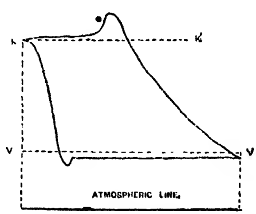



FIG. 25.—Diagram from Compressor indicating the binding of the Pressure Valve.

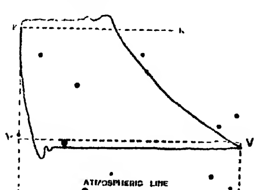



FIG. 26.—Diagram from Compressor indicating too great a resistance in the Pressure and Suction Valves.

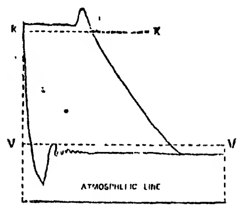



FIG. 27.—Diagram from Compressor indicating the binding of the Suction Valve.

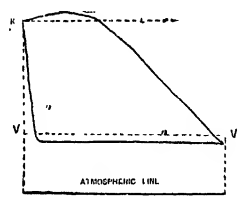



FIG. 28.—Diagram from Compressor indicating leaking of Compressor Valves.

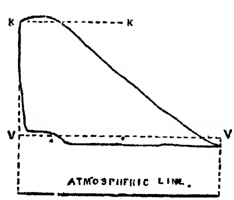



FIG. 29.—Diagram from Compressor indicating Defective Packing of Piston.

Fig. 27 indicates the binding of the suction valve by which a considerable decline is caused in the pressure at the beginning of the suction, which is consequently shown by an increased projection in the commencement of the suction line. At the beginning of compression this defect makes itself felt by causing a delay in the latter, which effect is also shown on this diagram.

Fig. 28 shows leaking of the compressor valves. In this diagram the projections in the compression and suction line do not appear, but the compression line gradually merges into the pressure line, and the back expansion line passes gradually into the suction line. If the leak in the pressure valve is the predominant one, then the compression curve will be almost in a straight line and very steep; if, on the contrary, the leak in the suction valve is the predominant one, then the compression line will run a rather flat course.

Fig. 29 indicates that the piston is not well packed, and, being leaky, the vapours are permitted to pass from one side of the piston to the other, thus causing a very gradual compression, and as a result a compression line having a flat course. On the other hand, a longer time will be taken before the suction line reaches its normal level on the return or backward stroke, inasmuch as the suction valve is prevented from opening until such time as the velocity of the piston becomes such that the amount of vapours leaking past the piston is insufficient in amount to fill the suction space. The pressure then gradually diminishes and the suction valve then begins to act, as is shown on the diagram.

It is to be understood that several of the defects above mentioned may exist at the same time.

## Management of Ammonia Compression Machines.

Every particular type of machine working on this principle has, as a rule, certain distinctive or characteristic features, and will, of course, so far at least as these are concerned, require special care and adjustment, and it would consequently be totally impossible to lay down an arbitrary set of rules for working that would be suitable to

all; nor is this necessary or required, as full particulars relating to the manipulation of each particular machine are invariably supplied by the makers. The following points, however, are more or less applicable to all machines working on the ammonia compression principle, and should therefore be familiar to those in charge of the same.

Before charging an empty machine with anhydrous ammonia, all air must first be carefully expelled. This is effected by working the pumps so as to discharge the air through special valves which are usually provided on the pump dome for that purpose.

The entire system should have been previously to this thoroughly tested by working the compressor, and permitting air to enter at the suction through the special valves provided for that purpose, and it should be perfectly tight at 300 lbs. air pressure on the square inch, and should be able to hold that pressure without loss. Whilst testing the system under air pressure, it should be also carefully blown through and thoroughly cleansed from all dirt, every trace of moisture being also removed.

It is totally impossible to eject all air from the plant by means of the compressor, therefore it is advisable to insert the requisite charge of ammonia gradually and not all at once, the best practice being to put in from 60 to 70 per cent. of the full charge at first, and cautiously permit the air still remaining to escape through the purging-cocks with as little loss of gas as possible, subsequently inserting an additional quantity of ammonia once or twice a day, until all the air has been got rid of by displacement, and the complete charge has been introduced.

To charge the machine, the dryer or dehydrator of the apparatus for manufacturing or generating anhydrous ammonia, or where no such apparatus is included in the installation, the drum or iron or steel flask of anhydrous ammonia should be connected, through a suitable pipe, to the charging valve; the expansion valve must be then closed, and the valve communicating with the dryer or dehydrator, or that in the flask or bottle, opened. The machine should be run at a slow speed when sucking ammonia from the drier, or whilst the flask is being emptied, with the discharge and suction valves full open.

In the latter case, when one of the said flasks or bottles has been completely emptied, it must be removed, the charging-valve having been first closed, and another placed in position, until the machine is sufficiently charged to work, when the charging-valve should be finally closed, and the main expansion valve opened and regulated. A glass gauge upon the liquid receiver will show when the latter is partially filled, and the pressure gauges, and the gradual cooling of the brine in the refrigerator (in the case of a brine circulation or ice-making apparatus), and the expansion pipe leading to the refrigerator coils becoming covered with frost, indicate when a sufficient amount to start working has been inserted.

It is sometimes advisable to slightly warm the vessels or bottles containing the anhydrous ammonia by means of a gas jet, or in some other convenient manner, whilst transferring their contents to the machine, as otherwise, if frost forms on the exterior of the said bottles, they will not be completely discharged, and loss of ammonia will ensue.

The flasks, bottles, or other receptacles containing the anhydrous ammonia should be always kept in a tolerably cool and a perfectly safe situation, and they should moreover be moved and handled with the utmost caution and care.

In the event of an accident occurring, and any considerable quantity of the ammonia becoming spilt, it is well to remember that it is so extremely soluble in water that one part of the latter at a temperature of 60° Fahr. will absorb some 800 parts of the ammonia gas, therefore water should be employed to kill or neutralise it, and any person attempting to penetrate an atmosphere saturated with this gas should not fail to place a cloth well saturated with water over his nose and mouth.

The machine having been started, and the regulating valve opened, it is essential to note carefully the temperature of the delivery pipe on the compressor, and if it shows a tendency to heat, then the said regulating valve must be opened wider; whilst, on the contrary, should it become cold, this valve must be slightly closed, the regulation or adjustment thereof being continued until the normal

temperature of the delivery pipe is the same as that of the cooling water leaving the condenser. When the charge of ammonia in the machine is insufficient, the delivery pipe will become heated, and that even when the regulating valve is wide open.

There are many additional signs of the healthy working of the apparatus other than the fact that it is satisfactorily performing its proper refrigerating duty, which soon become easily recognisable to those in charge; for example, every stroke of the piston will be clearly marked by a corresponding vibration of the pointers or indexes of the pressure and vacuum gauges. The frost visible on the exterior of the ammonia pipes leading to and from the refrigerator will be about the same. The liquid ammonia can be distinctly heard passing in a continuous and uninterrupted stream through the regulating valve. The temperature of the condenser will be about 15° higher than that of the cooling water running from the overflow. And finally, the temperature of the refrigerator will be about 15° lower than the actual temperature of the brine or the water being cooled.

Air will find its way into the system through leaky stuffing-boxes, improper regulation of the expansion valve, etc. Its presence in any considerable volume is shown by a kind of whistling noise, the liquid ammonia passing through the expansion valve in an intermittent manner, a rise of pressure in the condenser, and also loss of efficiency thereof, and other obvious signs. In this case the above air must be got rid of through the purging-cocks in a similar manner to that which remains in the system when first charging the machine.

The presence of any considerable amount of oil or water in the system, which may result from careless distillation, will cause a reduction in efficiency, and will be evidenced by shocks within the compressor cylinder.

The temperature can be regulated either by running the machine at a higher speed or by increasing the back pressure, or by a combination of both. The back pressure can be regulated by means of an expansion valve or valves fitted between the receiver and the refrigerator evaporating coils or pipes in the main liquid pipe.

### Leaks in Ammonia Apparatus.

Leaks are readily detected by the smell of the escaping ammonia gas when the machine is being filled; at a later stage, when working, their detection is not so easy. During the operation of the machine, when the liquor or brine in the tanks commences to smell of ammonia, it indicates a considerable leakage. It is recommended to test the liquor or brine periodically with Nessler's solution or otherwise.

Nessler's reagent, which is the best to use for the discovery of traces of ammonia in water or brine, consists of 17 grms. of mercuric chloride dissolved in about 300 cc. of distilled water, to which are added 35 grms. potassium iodide dissolved in 100 cc. of water, and constantly stirred until a slight permanent red precipitate is produced. To the solution thus formed are added 120 grms. of potassium hydrate dissolved in about 200 cc. of water, allowed to cool before mixing; the amount is then made up to 1 ltr., and mercuric chloride added until a permanent precipitate again forms. After standing for a sufficient time, the clear solution can be placed in glass-stoppered blue bottles and kept in a dark place.

If a few drops of this reagent be added to a sample of the suspected brine or water in a test-tube, or other small vessel, and the slightest trace of ammonia is present, a yellow colouration of the liquid will take place; a large quantity of ammonia will produce a dark-brown.

When the leaks are comparatively insignificant they can be closed in the usual way, by solder, using as a flux muriatic or hydrochloric acid killed with zinc. In some instances electric welding may be resorted to with advantage, or the leak may be closed by means of a composition of litharge and glycerine mixed into a stiff paste, bound with sheet-rubber, and covered with sheet-iron clamped firmly in position. When, however, the leak is at all serious, it is usually the better plan to at once put in a new coil, or a new length of pipe. See also pp. 173 to 175.

Before closing this chapter, a few words upon the excess condensing pressure invariably found in ammonia compression machines will not be out of place. This excess of the actual working condensing pressure over the theo-

retical is caused by the ammonia gas being imprisoned in the comparatively confined space afforded by the coils or pipes in the refrigerator, and the excess pressure is more marked in a horizontal compressor running at a high speed of, say, 140 revolutions per minute, than it is in vertical ones having only a low speed of from 35 to 60 revolutions per minute; it varies, moreover, in almost every make of compressor. At a low suction pressure of about 15 lbs. it should not be more than 10 lbs., but with a suction pressure of, say, 27 or 28 lbs. it may rise to 50 lbs., or even more.

The condensing pressure affords a means of ascertaining whether or not the apparatus contains the proper full charge of ammonia, or if the losses sustained by leakage are sufficient to render it necessary to insert an additional supply. For this reason it is advisable for the person in charge to keep a record in a proper book, suitably ruled for the purpose, of the temperature of the condensed ammonia when leaving the condenser, and also of the condensing and suction pressures, at regular intervals of, say, three hours. This will enable him to follow the state of the ammonia charge; for example, if the condensing pressure is found to be gradually falling during a three months' period, as compared with the average condensing pressure of the previous three months, whilst at the same time the condensing temperature and the suction pressure remain constant, it will be evident that the charge of ammonia has become reduced by leakage to a sufficient extent to require replenishing. This reduction in the condensing pressure is caused by the diminution in the charge of ammonia giving larger condenser space, the gas having thus a much more extended worm, coil, or tube space wherein to condense and liquefy, and hence the decrease. As a general rule, it may be taken that, whenever the condensing pressure is found to have fallen about 8 lbs., enough ammonia to restore the original condensing pressure should be inserted into the machine.

### Leaks in Carbonic Acid Machines.

To detect these, smear the joints with a solution of soap and water, and any leakage of gas will be evidenced by the

formation of bubbles. Carbon dioxide or carbonic acid being a completely inodorous gas, precautions are required to prevent the unnoticed occurrence of leakage.

## LUBRICATION OF REFRIGERATING MACHINERY.

This important point is apt to be as much neglected by users of refrigerating machinery as it is by those of other types of machinery. It would be well for these gentlemen to at once dismiss from their minds the idea that low-priced inferior quality oils are really the cheapest, and understand that, on the contrary, not only are high-grade oils necessary to ensure the highest efficiency of the machinery, but that they are also the least expensive in the long run.

In refrigerating machinery the use of three different kinds of oil is demanded, viz. steam cylinder oil; oil for general use; and compressor pump oil:—

Oil for the steam cylinder. Good cylinder oil is entirely free from grit, does not gum up the valves and cylinder, and does not evaporate rapidly on exposure to the heat of the steam. The quality of a cylinder oil is demonstrated on removal of the cylinder head. If the oil is of good quality, the wearing surfaces should appear well coated with lubricant, which will not show a gummy deposit, or blacken on the application of clean waste.

Oil for general use on all the bearings and wearing surfaces of the machine proper: This may be any oil that will not gum, is not too limpid, possesses a good body, is free from grit and acids, is of good wearing quality, and flows freely from the oil-cups at a fine adjustment without a tendency to clog. For the larger bearings it is well to use a heavier grade of oil.

Oil for use in compressor pumps: This should be what is known as zero oil, or cold test oil, that is to say, it should be capable of withstanding a very low temperature without freezing, and it should be of the best quality. American makers recommend the use of the best paraffin oil, and clear West Virginia crude oil.

Mr. F. E. Matthews, in dealing with this subject in "Power and the Engineer," New York, says, that in order that the oils used in the system shall not stiffen prohibitively at the low temperatures encountered, and not be saponified

by the ammonia, only very light mineral oils can be employed. Such oils range from 22° to 30° Bé., corresponding to a specific gravity of from 0·924 to 0·88. These oils should have a cold test of about zero Fahrenheit, to obtain which they will have a flash point of between 310° and 400° F. This low flash point implies that a considerable amount of vapour will be given off at a much lower temperature. Since discharge temperatures of compression machines often approach these temperatures, it is obvious that a considerable amount of oil will pass to the condenser, not as a liquid but as a vapour. Under such conditions, since there is no material cooling effect in the oil separator, only liquid oil would be precipitated at that point.

### Effect of a Coating of Ice on Direct Expansion Pipes. Defrosting Refrigerating Coils. Incrustation on Condenser Coils.

The effect of a coating of ice on direct expansion pipes, according to an authority (Mr. F. E. Matthews) writing in "Power and the Engineer," New York, may be shown as follows: Assuming a heat transfer of 10 B.T.U., in round numbers per hour, per square foot per degree of difference in temperature inside and out, for a flat metallic refrigerating surface, and an equal amount of sheet ice one inch thick, it follows that the heat transmission through a square foot of direct expansion cooling surface insulated with a layer of ice one inch thick will be only one-half that of the uncoated surface. As a matter of fact, it would seem from the context that the value of 10 B.T.U. given as the heat conductivity of ice applied to plate-ice conditions under which the wetted surface of the submerged ice will transmit materially more heat than a dry surface in contact with air. This would indicate that the decrease in heat-transmitting capacity of direct expansion surfaces in air due to a coating of ice is even more than 50 per cent. This condition will be partially offset by the fact that on account of the increasing diameter, the layer of ice in the case of cylindrical surfaces such as pipes (which, together with the fact that such coatings usually present an irregular surface, further increase the heat-absorbing area) may increase the heat

transmission, sufficiently to make up for, the lesser heat transfer between the air and dry ice, and make 50 per cent. at least, a reasonable estimate of the loss in heat-absorbing capacity due to one inch of ice.

Under average commercial conditions of intermittent frosting a square foot of direct-expansion surface in air is usually credited with a heat-transmission of only from 2 to 4 B.T.U. per hour per degree difference in temperature.

Brine pipes may be readily defrosted by the circulation of hot brine. This may be accomplished through the main feed and return headers where the operation does not have to be performed very frequently, or, as in abattoirs, where the excessive amounts of moisture from the hot meats to be chilled make the accumulation of frost very rapid, or by a separate set of defrosting headers.

In the case of direct-expansion coils, the defrosting method probably most satisfactory where the cold-storage temperatures are above 32° F. is to install sufficient coil surface to allow a part of the coils to be shut off at any time, so that the frost will melt without artificial heat, and at the same time produce a certain amount of useful refrigeration. If it is necessary to force the defrosting process by the use of outside heat, a hot gas line from the condenser may be connected to the liquid-line connections to the separate coils just inside the expansion valves. The hot gas, after melting the ice as it passes through the coils, returns to the compressor together with the return gas from the remaining coils.

Where the temperatures carried in the cold-storage compartments are below 32° F., and in which the defrosting cannot be effected without the use of artificial heat, often very objectionable, two methods are available, viz., that of forcibly removing the ice with scrapers, and that of suspending over the pipes trays of calcium chloride. This substance is an exceedingly deliquescent salt, which in absorbing moisture from the air forms a saturated calcium brine which freezes at a very low temperature. In trickling down over the coils, the brine melts the ice, forming a more dilute brine which is then conducted away to the sewer, or, if the quantities involved warrant the expenditure of labour, may be evaporated and the calcium chloride recovered.

While the comparatively high working temperature of condenser coils, together with the usually ample provisions for draining each separate coil, prevents the accumulation of such large quantities of oil as are often lodged in expansion coils, condenser coils are exposed to another source of loss of efficiency from without, where the available cooling water is abnormally hard or carries a large amount of suspended matter. Ammonia condensers, and especially steam condensers, soon become coated with a deposit of scale or mud, which, if not properly removed, becomes a more or less effective insulator according to the composition of the deposit. The heat conductivity of metallic surfaces is not the same per degree difference in temperature at medium and low as it is for high temperatures, and it does not therefore follow that the resistance offered by the scale accumulating on the outside of atmospheric and submerged ammonia and steam condensers is the same as that of scale on the inside of a boiler. However, some slight idea of the extent of the loss may be gained from the fact that in steam-boiler practice, the insulating effect of scale results in thermal loss corresponding to 2 per cent. of the fuel for each $\frac{1}{64}$ in. in thickness of scale. Condenser surfaces like those of steam boilers, expansion coils or any other heat-transmitting surfaces, should be kept as free as possible from deposits of foreign matter.

### The Foaming of Brine.

Trouble is sometimes experienced with brine foaming when drawing the ice in plants on the can system. When this foam is thick it is liable to get into the cans when replaced in the ice-making tank and spoil the water for the purpose of ice-making. Foaming may be caused by too large a number of cans being drawn from the ice-making tank together, and the level of the brine therein consequently falling below that of the suction to the brine pump, thus allowing the ingress of air.

## TESTING VAPOUR COMPRESSION MACHINES.

(*J. Wemyss Anderson, M.Eng., "Proceedings, Inst. of Mech. Engrs., 1912."*)

### DATA REQUIRED.

*Compressor.*

Type ...................... .......... { Double or single acting, horizontal or vertical. If fitted with water-jacket extra records to be inserted accordingly. }

Diameter ..............
Stroke..................
Clearance.—Back............ Volume..... .........
Front............ Volume.. .. ......
Diameter of compressor rod............. .
Volume swept through by compressor piston per revolution..............

*Condenser.*

Type...............
Diameter of pipe { Internal............... External.............. }
No. of sections..............
Length of pipe in each section..... .......ft.
Total length of pipe...............ft.
Estimated heating surface { Internal....... .. ...sq. ft. External.. ..sq. ft. }
Material of pipe...................... ...... ..
Remarks *re* circulation of water......... ... ..

*Evaporator.*

Same as for condenser, and in addition—
Method (if any) for agitating the brine ..... ... ...........
Insulated or in insulated space................

*Brine.*

Salt employed..............
Tables of specific heats and specific gravities of the brine for ranges of temperature used in the test..........................................

*Note.*—It is better to run the machine for some hours before observations are taken in order to avoid allowances, which otherwise must be made due to varying temperatures and consequently varying specific heats of the brine.

Methods of measuring and checking the quantities of brine circulated.

*Refrigerant.*

Outline description of method employed for measuring the quantity (weight) of refrigerant circulated.

*Water.*

Methods of measuring and checking the quantities of water circulated.

*Remarks.*—Quality of water (town supply, well, canal, sea-water, etc. Hard or soft). Note if the water-supply be heated to a stated temperature before use, etc.

*Regulating Valve.*

Outline description. Record of movement (if any) during the test.

*Temperatures.*

Detailed account of method or methods adopted for reading temperatures.

*General Remarks.*

Outline description of any particular fitting likely to affect the test, such as a drier between the evaporator and compressor.

Amount of refrigerant in the machine. Interval of time between charging and testing the machine. Precautions taken to eliminate air or other foreign gases from both the refrigerant and brine circuits.

OBSERVATIONS REQUIRED.

Date.............. Atmospheric conditions..............
Number of trial..............
Duration.................

*Compressor.*

(1) Indicated horse-power.... ..........
(2) Heat equivalent of (1)...............B.Th.U.
(3) Vapour entering compressor. Temp.............. Pressure...........
(4) „ leaving „ Temp.............. Pressure...........

*Condenser.*

(5) Temperature of water, inlet...............
(6) „ „ outlet...............
(7) „ „ difference (5) and (6) .............
(8) Quantity of water circulated..............
(9) Heat rejected by condenser ..............B.Th.U.
(10) Vapour entering condenser. Temp.............. Pressure...........
(11) Liquid leaving „ Temp.............. Pressure...........

*Evaporator.*

(12) Temperature of brine, inlet...............
(13) „ „ outlet..............
(14) „ „ difference (12) and (13)..............
(15) Quantity of brine circulated..............
(16) Allowance ± B.Th.U. for variations in (12) and (13) during trial..............
(17) Net refrigerating effect ...............B.Th.U.
(18) Refrigerant entering evaporator. Temp........... Pressure, .........
(19) „ leaving „ Temp........... Pressure...........

*Heat Balance.*

(20) Net refrigerating effect (17) ...............B.Th.U.
(21) Heat equivalent of work expended in compressor (2) ..............B.Th.U.
(22) Total heat imparted to refrigerant (20) and (21) ..............B.Th.U.
(23) Total heat rejected at condenser (9) ...............B.Th.U.
*(24) Difference between (22) and (23) ..............B.Th.U.

*Efficiency.*

(25) Heat equivalent of energy supplied to machine...............B.Th.U.
(26) Coefficient of performance (*a*). Ratio of (2) to (17)......... . ...
(27) Coefficient of performance (*b*). Ratio of (25) to (17)...... ......
(28) Efficiency of driving. Ratio of (25) to (2)............................
(29) Capacity of machine. Ice melting per day of 24 hrs...............

*General.*

(30) Weight of refrigerant circulated ............lb.
(31) Estimated refrigerating effect from (30)..............
(32) Difference between (17) and (31) ..............B.Th.U.
(33) Temperature of liquid refrigerant before passing the regulating valve..............

* This difference is generally fairly large. In commercial machines due allowances are made for "heat leakage" into the pipes and connections. *See* Table, page 203.

## SUGGESTED FORM FOR ENGINEER'S DAILY REPORT.

*Department No.*________ *Engineer's Daily Report.* *Date*____________

| | Engine Room. | | | | | | | | | Refrigerator Temperature. | | | | | | | | | | | | Water Condenser. | | | Weather. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Revolutions. | | | | | | | | | | | | | | | | | | | | | | | | |
| Hour. | Direct pressure. | Suction pressure. | No. 1 Engine. | No. 2 Engine. | No. 3 Engine. | No. 4 Engine. | Brine or salt water column. | Steam. | Vacuum. | No. 1 Room. | No. 2 Room. | No. 3 Room. | No. 4 Room. | No. 5 Room. | No. 6 Room. | No. 7 Room. | No. 8 Room. | No. 9 Room. | No. 10 Room. | No. 11 Room. | No. 12 Room. | Initial temperature to ammonia condenser. | Temperature of water on entering steam condenser. | Final temperature of water on leaving steam condenser. | Temperature. | Conditions. | Remarks. |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Engines. Hours run. | | | | Boilers. Hours run. | | | | Fuel. Coal receipts. | Refrigeration daily in tons. | Brine or salt water column. | Gallons to date. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine. | Up to present date. | To-day. | Total. | Boilr. | Up to present date. | To-day. | Total. | | | | |
| No. 1 | | | | No. 1 | | | | | | | |
| ,, 2 | | | | ,, 2 | | | | | | | |
| ,, 3 | | | | ,, 3 | | | | | | | |
| ,, 4 | | | | ,, 4 | | | | | | | |
| | | | | ,, 5 | | | | | | | |
| | | | | ,, 6 | | | | | | | |
| | | | | ,, 7 | | | | | | | |
| | | | | ,, 8 | | | | | | | |

*Engineer's Signature*____________

# SECTION VI

## GENERAL TABLES AND MEMORANDA.

### LIGHTING COLD STORES.

IT is desirable that daylight should not be allowed to enter a cold store, and therefore artificial light is usually resorted to, electric light being invariably employed, owing to there being practically an absence of heat therefrom.

Incandescent lamps should be always used inside the cold stores, but arc lamps may be placed, if desired, in the engine-room, and employed for the external lighting of the premises. Lower voltage lamps are the most durable, and serve the purpose quite as well as those of a higher voltage.

The mains should be kept as far as practicable in the corridors, and tinned cables of high conductivity and with rubber insulation should preferably be employed.

Iron piping, steel conduits, or wood casing, may be used for carrying the main cables, the latter being the cheapest both in cost of material and in fixing, and also lending itself more readily to any subsequent alterations that may become necessary. Steel conduits, however, possess several important advantages. The steel-armoured insulating conduit material now much used is installed in a similar manner to ordinary gas-pipe construction, the principal difference in electric piping being that specially insulated boxes, bends, elbows, etc., are substituted for the ordinary tees or angles of a gas-pipe system. The use of the conduit system

ensures a mechanically and electrically protective duct for the installation of the electric conductors.

When wood casing is used, the interior should be painted with asbestos paint, and the cover fixed with brass screws on each edge, not in the central fillet.

Iron piping has an internal lining of suitable insulating material, and is, as a rule, coated with a bituminous compound of some description intended to act as a preservative.

There are two systems of carrying out wiring now in use, viz. the tree system, and the distributing-board system.

In the first of these, or the tree system, two main cables are carried through the building, the branch circuits being all taken from these cables or mains. In the second, or distributing-board system, a main switchboard is placed close to the dynamo, from which main switchboard cables are carried to supplementary distributing boards located at convenient points, from which the lamps are wired.

An obvious advantage of this latter plan is that all the joints are readily get-at-able, being at the distributing boards and fittings. The insulation of the cable is left completely intact.

In fixing wood casing all joints should be united, and no sharp edges or corners left for the cable to pass over. The casing is ordinarily secured by screws to the walls, floors, and ceilings, and either on the surface, partially sunk, or sunk flush therewith. In very damp situations, however, the casing should be supported, so as to be clear of the surfaces, by means of small porcelain insulators.

The circuits may be arranged either on the series system or on the parallel arrangement, the latter being the most common, and the former being, as a rule, only employed where a number of arc lamps are used. The series circuit and parallel circuit are shown in the diagrams (Figs. 30 and 31), the dynamos, main cables, lamps, and switches being indicated thereon.

In the series circuit the current is maintained constant in value, the difference in pressure varying with the work on the circuit.

In the parallel circuit all the lamps are connected as separate paths between the two main leads, each path being quite independent of the other paths. The difference of electrical pressure is maintained constant, the current varying with the work that is on the circuit. The switching off of a

lamp causes a break in the wires connecting the lamp to the circuit.

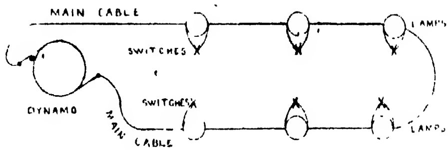



FIG. 30.—Diagram illustrating Arrangement of Electric Lighting on the Series Circuit System.

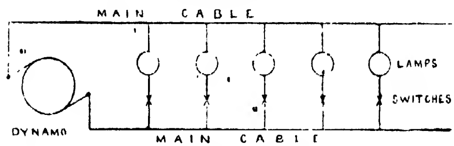



FIG. 31.—Diagram illustrating Arrangement of Electric Lighting on the Parallel Circuit System.

## CREAMERY COLD STORAGE.

A bulletin entitled "Creamery Cold Storage" written by Mr. J. A. Ruddick, the Dairy Commissioner, Canadian Department of Agriculture, goes very fully into the subject and contains much valuable information, the following particulars being abstracted from this source.

Butter is an unstable product. It is at its best when freshly made. Strictly speaking, deterioration begins at once, and it will become noticeable sooner or later according to the conditions under which the butter is kept. The most important condition in this respect is that of temperature, because no other condition has anything like the same influence in the preservation of butter. The preservation of butter means the checking to a greater or less extent of the processes of fermentation that affect the flavour, and which are inevitable in all butter, but it has never been found that even such extreme low temperatures will preserve the flavour indefinitely, although it has been proved beyond doubt that the lower the temperature the longer it will be preserved, other things being equal. Fortunately there is a

certain period in the life of all good butter during which it may be considered to be at its best. Assuming that the butter has been well made, the duration of this period depends almost entirely on the temperature at which the butter is kept.

Mechanical refrigeration is indispensable where low temperatures are required, as in a modern cold storage warehouse, and it may be employed with advantage in creameries having a large output of butter. For small or medium sized creameries, however, the first cost of installation, and the annual expense of operation, put the mechanical system out of the question. The following are examples of creamery refrigerators designed by Mr. Ruddick, adapted to be cooled by ice, but it will be understood that the buildings with certain simple modifications would be suitable for the installation of machinery for mechanical refrigeration.

THE AIR CIRCULATION SYSTEM:—Although it may be *possible* to secure rather lower temperatures with the cylinder system than can be obtained with the air circulation system, all things considered, a lower average temperature is usually found where the air circulation system is in use. Both the ice chamber and the cold storage room are thoroughly insulated. Figs. 32 and 33 show plan and section of a creamery refrigerator on the air circulation system. It will be seen that there is a connection between the two rooms which provides for the circulation of air over the ice and through the cold storage chamber. The working of such a refrigerator is automatic, and requires only to be regulated by the opening and closing of the slides that control the circulation of air. The ice is not covered, as the thorough insulation of the walls of the ice chamber is depended on to prevent undue waste of ice.

THE CYLINDER SYSTEM:—In this system galvanized iron cylinders about one foot in diameter are placed in the cold storage room so as to extend from the floor to the ceiling and opening into the room or loft above. A row of these cylinders should extend along at least one-fourth of the wall space of the storage room. The cylinders are filled from above with crushed ice and salt, the proportion of which

may be varied according to the temperature desired. The larger the proportion of salt the better the results will be, until the maximum is reached at about 1 part of salt to 3 of ice. Drainage must be provided to carry off the water from the melting ice, and the outlet should always be trapped in order to prevent the passage of air. The ice for this system is usually stored in an ordinary ice shed, covered with sawdust, cut hay or other insulating material. The

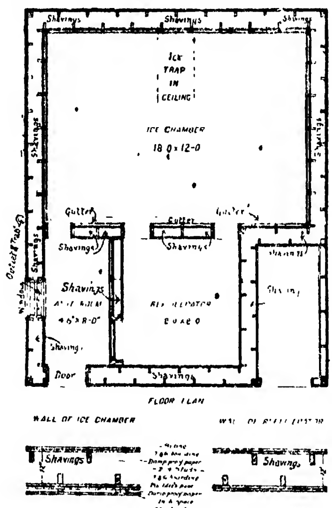



Fig. 37.—Creamery Refrigerator on the Air Circulation System. Plan view.

cylinders must be kept full in order to secure the maximum of refrigeration. The labour of breaking the ice and filling the cylinders is very considerable and constitutes one of the chief objections to the cylinder system. Where the refrigeration depends upon the daily performance, by the butter maker, of this item of labour, it is very apt to be more or less neglected. If the cylinders are allowed to become partially empty, there is a corresponding rise of

temperature, in the storage room, and this is what very often occurs. The cylinder system is the cheapest to install, because the storage room only need be insulated, but the large amount of labour involved in keeping the cylinders properly filled, and the cost of the salt, make the operation of this system somewhat expensive. Where there is plenty of cheap labour and someone to take sufficient interest in the question to see that the work is properly attended to,

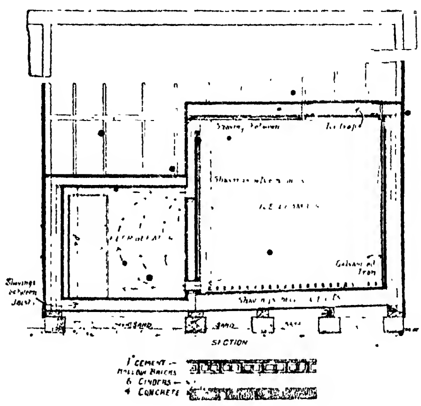
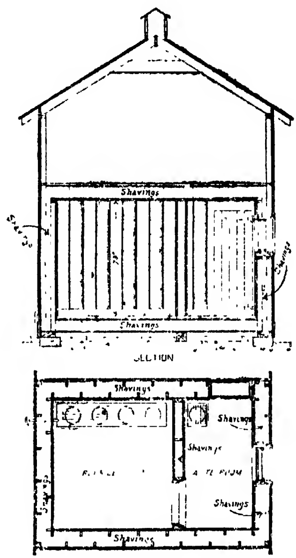



FIG. 33 — Creamery Refrigerator on the Air Circulation System. Sectional view.

there is no doubt but this system will give good results, as far as ice goes, for the storage of butter. Figs. 34 and 35 shows plan and section, and Figs. 36 and 37 details of a creamery refrigerator on the cylinder system.

INSULATION :—In the construction of insulated walls, the best practice at the present time provides for an outer and an inner shell, as nearly as practicable impervious to air and dampness, with a space between to be filled with some non-conducting material. The width of the space will depend on the filling to be used and the temperature to

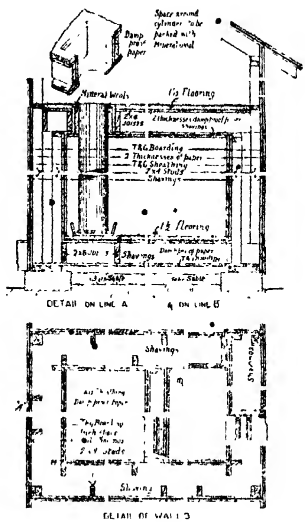
be maintained in the storage room. For a creamery cold storage constructed of wood, there is no better material for filling spaces than planing mill shavings. The weight of shavings required to fill a given space will depend somewhat on the kind of wood from which they are made, and also to some extent on how tightly they are packed, but a fair average is from 7 to 9 pounds per cubic foot of space. They should be packed sufficiently to prevent future settling.




FIGS. 34 and 35.—Creamery Refrigerator on the Cylinder System. Plan and Section

INTERIOR FINISH OF ROOMS:—All inside sheathing should be of spruce, because of its odourless character. The inside surface of ante-rooms and cold storage rooms should receive a coat of shellac, or hard oil. This will permit of the walls being thoroughly washed and disinfected

to destroy spores of mould. Whitewash is also used as an interior finish. It is cheap and can be renewed from time to time. A little salt mixed with whitewash is said to harden it, and thus prevent it from rubbing off when touched.




FIGS. 36 and 37.—Creamery Refrigerator on the Cylinder System. Detail views.

If the inside sheathing of the ice chamber is coated with paraffin wax, like a butter box, the lumber will be preserved and moisture prevented from getting into the insulation.

SIZE OF ICE CHAMBER:—It is impossible to lay down any rule as to the total quantity of ice required for creameries with a given output, as so much depends on what the ice is used for, and also on the nature of the water supply. In many creameries, where there is an ample supply of

cold water, no ice is used for cream cooling, while for others a large quantity is provided for that purpose. If a pasteurizer is used, the extra cooling required increases the consumption of ice very considerably. It is important, however, to estimate correctly the size of the ice chamber required for a cold storage on the circulation system. Where this system is used the supply of ice for cream cooling purposes should be kept separate from the cold storage supply. The ice chamber should not be opened during the summer except for occasional examination. The quantities given in the following table will be found to be about right for average circumstances:—

| Pounds of Butter made during Summer Months. | Tons of Ice required for Butter Storage only. | Size of Ice Chamber in cubic feet. |
|---|---|---|
| 200,000 | 140 | 5,000 |
| 100,000 | 80 | 3,000 |
| 50,000 | 50 | 2,000 |

Where ice is required for cream cooling purposes, and it generally is, about one-half the quantity given in the table will be required in addition. This can be stored in an ordinary ice shed and covered with sawdust.

GENERAL:—Creamery refrigerators on the air circulation and on the cylinder systems consists of: (1) An insulated ice chamber, where the ice is kept without any covering. (2) A cold storage room, where the packages of butter for export only shall be stored. (3) An ante-room, to receive retail butter, and to protect the storage room against the entrance of warm air. Both cold storage room and ante-room are cooled by the circulation of the air which passes over the ice in the ice chamber. The situation should be at the north end of the creamery, or sheltered from the direct rays of the sun if possible.

The size will be determined by the output of the creamery. Butter should be shipped every week wherever possible, and in this case the cold storage room should not be much larger than necessary to hold a week's make,

with convenience for handling the packages. A room 7 feet high by 8 feet square inside will hold conveniently 120 boxes, piled six high. The ante-room should be large enough so that the door can be conveniently closed before opening the door of the cold storage room.

As regards light it is not desirable to have a window in the cold storage room. Sufficient light can be had from a lamp or candle when necessary. A window may be put in the ante-room.

Good insulation should be provided on all sides of the refrigerator, around cold storage room and ante-room, whether adjoining the ice chamber or any other part of the creamery, all must be equally well insulated.

MATERIALS :—*Wood.*—All lumber employed must be thoroughly dry and sound without loose knots or shakes, and must be odourless. Spruce and hemlock are the best in the order named. Pine is not suitable for inside sheathing, on account of its odour. All boards employed should be dressed as well as tongued and grooved. Unseasoned lumber must be carefully avoided. When building in winter, fires must be kept going so as to have all materials as dry as possible. This is very important, as dampness in insulation destroys its efficiency.

*Paper.*—All papers used should be strictly odourless and damp-proof. Tar paper, felt paper, straw paper, rosin sized paper, and all other common building papers are not suitable and must not be used. Use double thickness of paper in all cases, each layer lapping 2 inches over preceding one. The layers should extend continuously around all corners. All breaks to be carefully covered.

*Shavings.*—Shavings must be thoroughly dry, free from bark or other dirt. Shavings from some odourless wood, such as hemlock, spruce or white wood, to have the preference.

### TO CHARGE AN AMMONIA MACHINE.

The following tables given by Mr. F. E. Matthews in an article in "Power and the Engineer," New York, will be found useful when calculating the amount of ammonia required to charge a system :—

TABLE I. RELATION OF CUBICAL CONTENTS TO RUNNING FEET IN PIPES OF VARIOUS SIZES.

| Size of Pipe, Inches. | Running Foot per Cubic Foot of Contents. | Contents in Cubic Feet per 100 Running Feet. |
|---|---|---|
| ¾ | 270·00 | 0·370 |
| 1 | 166·90 | 0·599 |
| 1¼ | 96·25 | 1·038 |
| 1½ | 70·65 | 1·415 |
| 2 | 42·36 | 2·360 |

Having found the number of feet run of pipe in system, the cubic feet contained in it may be found from Table I. The amount of ammonia required is found by multiplying the cubical contents by the weight of gas per cubic foot corresponding to the pressure to be carried in the pipes when the system is in operation. A liberal allowance must be made for reserve liquid in the receiver, evaporating liquid in the expansion coils, and condensing liquid in the condenser.

TABLE II. WEIGHTS OF AMMONIA VAPOURS AT DIFFERENT GAUGE PRESSURES.

| Ammonia Gauge Pressure. | Weight of 1 Cubic Foot of Vapour, Lb. | Ammonia Gauge Pressure. | Weight of 1 Cubic Foot of Vapour, Lb. |
|---|---|---|---|
| 0 | 0·0566 | 80 | 0·3304 |
| 10 | 0·0941 | 90 | 0·3617 |
| 20 | 0·1269 | 100 | 0·3939 |
| 30 | 0·1611 | 125 | 0·4766 |
| 40 | 0·1955 | 150 | 0·5566 |
| 50 | 0·2292 | 175 | 0·6340 |
| 60 | 0·2641 | 200 | 0·7188 |
| 70 | 0·2965 | ... | ...... |

TABLE III. ANHYDROUS AMMONIA REQUIRED FOR THE COMPRESSION SIDE OF REFRIGERATING PLANTS.

| Tons of Refrigeration. | Pounds of Ammonia. | Tons of Refrigeration. | Pounds of Ammonia. |
|---|---|---|---|
| 5 | 110 | 75 | 375 |
| 10 | 150 | 100 | 440 |
| 15 | 185 | 150 | 510 |
| 20 | 230 | 175 | 570 |
| 25 | 245 | 200 | 620 |
| 30 | 270 | 225 | 675 |
| 35 | 290 | 250 | 725 |
| 40 | 300 | 300 | 840 |
| 45 | 325 | 400 | 1040 |
| 50 | 350 | 500 | 1215 |

TABLE IV. ANHYDROUS AMMONIA REQUIRED PER 100 RUNNING FEET OF PIPE—EXPANSION SIDE.*

| REFRIGERATING PLANTS. Direct Expansion and Brine Cooling Coils. | Size of Pipe. | ICE PLANTS. Expansion Coils for Can and Plate use. |
|---|---|---|
| 14 pounds. | 1 inch. | 8 pounds. |
| 18 pounds. | 1¼ inches. | 11 pounds. |
| 20 pounds. | 1½ inches. | 12 pounds. |
| 25 pounds. | 2 inches. | 15 pounds. |

* Commercial practice. Refrigerating machinery operated under average conditions.

TABLE V. AMMONIA REQUIRED FOR ICE MAKING PLANTS.

| | | | | | | |
|---|---|---|---|---|---|---|
| Tons of ice per 24 hours............ | 5 | 10 | 15 | 25 | 50 | 100 |
| Pounds Ammonia.................... | 100 | 250 | 500 | 1000 | 2000 | 4000 |

The amounts given in this table are for the total number of pounds required to charge both high- and low-pressure sides of ice-making systems.

## EXPERIMENTS IN WORT COOLING.

The following tabulated experiments of the performance of a tubular refrigerator for wort cooling are gleaned from *Engineering*. The water and wort are moved in opposite directions, the former through thin metallic tubes, which are surrounded by the wort to be cooled :—

| Area of Cooling Surface of Refrigerator. | WORT. | | | | | WATER. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Specific Gravity. | Quantity passed through per Hour. | Initial Temperature. | Final Temperature. | Cooled down. | Quantity passed through per Hour. | Initial Temperature. | Final Temperature. | Warmed up. |
| Square Feet. | | Bbls. | Fahr. | Fahr. | Fahr. | Bbls. | Fahr. | Fahr. | Fahr. |
| No. 1. 881 | — | 33·9 | 212° | 72° | 140° | 61·1 | 65° | 169° | 104° |
| No. 2. 514 | 1·104 | 36·1 | 155 | 59 | 96 | 75·5 | 54 | 100 | 46 |
| No. 3. 514 | 1·188 | 36·6 | 191 | 59 | 132 | 99·5 | 54 | 100 | 46 |
| No. 4. 514 | 1·035 | 47·3 | 193 | 59 | 134 | 90·7 | 54 | 100 | 46 |
| No. 5. 514 | 1·018 | 48·0 | 178 | 59 | 119 | 102·0 | 54 | 100 | 46 |

NOTE 1.—A barrel contains thirty-six gallons, or 360 lbs. of water.

NOTE 2.—The temperature of the air in Nos. 2 and 4 was 44° F., and in Nos. 3 and 5, 40° F.

TABLE SHOWING THE TENSION OF AQUEOUS VAPOUR IN MILLIMETRES OF MERCURY, FROM −30° C. TO 230° C. —(*Siebert.*)

| Temp. | Tension. | Temp. | Tension. | Temp. | Tension. | Temp. | Tension. |
|---|---|---|---|---|---|---|---|
| −30° | 0·39 | 21° | 18·5 | 94·0° | 610·4 | 104° | 876 |
| −25 | 0·61 | 22 | 19·7 | 94·5 | 622·2 | 105 | 907 |
| −10 | 0·9 | 23 | 20·9 | 95·0 | 633·8 | 107 | 972 |
| −15 | 1·4 | 24 | 22·7 | 95·5 | 645·7 | 110 | 1,077 |
| −10 | 2·1 | 25 | 23·6 | 96·0 | 657·5 | 115 | 1,273 |
| −5 | 3·1 | 26 | 25·0 | 96·5 | 669·7 | 120 | 1,491 |
| −2 | 4·0 | 27 | 26·6 | 97·0 | 682·0 | 125 | 1,744 |
| −1 | 4·3 | 28 | 28·1 | 97·5 | 694·6 | 130 | 2,030 |
| 0 | 4·6 | 29 | 29·8 | 98·0 | 707·3 | 135 | 2,354 |
| 1 | 4·95 | 30 | 31·6 | 98·5 | 721·2 | 140 | 2,717 |
| 2 | 5·3 | 35 | 41·9 | 99·0 | 732·2 | 145 | 3,125 |
| 3 | 5·7 | 40 | 55·0 | 99·1 | 735·9 | 150 | 3,581 |
| 4 | 6·1 | 45 | 71·5 | 99·2 | 738·5 | 155 | 4,088 |
| 5 | 6·5 | 50 | 92·0 | 99·3 | 741·2 | 160 | 4,551 |
| 6 | 7·0 | 55 | 117·5 | 99·4 | 743·8 | 165 | 5,274 |
| 7 | 7·5 | 60 | 148·0 | 99·5 | 746·5 | 170 | 5,961 |
| 8 | 8·0 | 65 | 186·0 | 99·6 | 749·2 | 175 | 6,717 |
| 9 | 8·6 | 70 | 232·0 | 99·7 | 751·9 | 180 | 7,547 |
| 10 | 9·1 | 75 | 287·0 | 99·8 | 754·6 | 185 | 8,453 |
| 11 | 9·7 | 80 | 354·0 | 99·9 | 757·3 | 190 | 9,443 |
| 12 | 10·4 | 85 | 432·0 | 100·0 | 760·0 | 195 | 10,520 |
| 13 | 11·1 | 90 | 525·4 | 100·1 | 762·7 | 200 | 11,689 |
| 14 | 11·9 | 90·5 | 535·5 | 100·2 | 765·5 | 205 | 12,956 |
| 15 | 12·7 | 91·0 | 545·8 | 100·4 | 772·0 | 210 | 14,325 |
| 16 | 13·5 | 91·5 | 556·2 | 100·6 | 776·5 | 215 | 15,801 |
| 17 | 14·4 | 92·0 | 566·2 | 101·0 | 787·0 | 220 | 17,390 |
| 18 | 15·3 | 92·5 | 577·8 | 102·0 | 816·0 | 225 | 19,097 |
| 19 | 16·3 | 93·0 | 588·4 | 103·0 | 845·0 | 230 | 20,926 |
| 20 | 17·4 | 93·5 | 599·5 | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees C..... | 120 | 134 | 144 | 152 | 159 | 171 | 180 | 190 | 213 | 235 |
| Atmospheres .. | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 | 25 |

TABLE OF PHYSICAL CONSTANT OF GASES.—(*Peckham.*)

| | Critical Temp. Centigrade. | Critical Pressure Atmospheres. | Boiling-point at Ordinary Pressure. | Freezing-point Centigrade. | Freezing Pressure Mm. | Density of Gas. | Density of Liquid at Boiling-point. | Colour of Liquid. |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide, $CO_2$ ... ... | 31[1] | 77·0 | −78·2[3] | −79[3] | 760 | 22 | 0·830[4] | Colourless |
| Ethylene, $C_2H_4$ ... ... ... | 95·0 | 44·0 / 53·0 | −110[5] | ... | ... | 14 | ... | ... |
| Hydrogen, $H_2$ ... ... ... ... | −234·5[6] (Theor.) | 20·0 | −243·5[6] (Theor.) | ... | ... | 1 | ... | Colourless |
| Nitrogen, $N_2$ ... ... ... ... | −146 | 35·0 | −194·4 | −203 to −214 Mean −280° | 60 | 14 | 0·885 | Colourless |
| Carbonic Oxide, CO ... ... | −139·5 | 35·5 | −190·0 | −207·0 | 100 | 14 | ... | Colourless |
| Argon, A ... ... ... ... ... | −121·0 | 50·6 | −187·0 | −189·6 | ... | 19·9 | about 1·5 | Colourless |
| Air ... ... ... ... ... ... | −140·0 | 39·0 | −191·0 | −207[9] | ... | ... | 0·933 | Bluish |
| Oxygen, $O_2$ ... ... ... ... | −118·8 | 50·8 | −182·7 | ... | ... | 16 | 1·124 | Bluish |
| Nitric Oxide, NO ... ... ... | −93·5 | 71·2 | −153·6 | −167·0 | 138 | 15 | ... | Colourless |
| Marsh Gas, $CH_4$ ... ... ... | −81·8 | 54·9 | −164·0 | −185·8 | 80 | 8 | 0·415 | Colourless |
| Helium, He ... ... ... ... | ... | ... | Below −264[7] (Theor.) | ... | ... | 2·02[8] | ... | ... |
| Fluorine ... ... ... ... ... | ... | ... | −187 | ... | ... | ... | ... | ... |

[1] Andrews, *Deschanel Nat. Phil.*, II., 352.
[2] Villard & Jarry, *Comptes Rendus*, 1895, 120, 1413.
[3] Regnault, *Muspratt's Chemie*, IV., 1620.
[4] Thilorier, *Muspratt's Chemie*, IV., 1626.
[5] Fownes, *Elem. Chem.*, 12th ed., p. 534.
[6] Olzewski, *Phil. Mag.*, 1885 (5), 40; 202.
[7] Olzewski, *Ann. Phys. Chem.*, 1896 (2), 59, 184.
[8] Cleve, *Comptes Rendus*, 1895, 120, 1212.
[9] Dewar.

TABLE SHOWING PROPERTIES OF SATURATED STEAM.—*Yaryan.*

| Absolute Pressure from Vacuum. | | Above Atmosphere. | | Temperature. | Total Heat in British Units. | Heat of Vaporization or Latent Heat. |
|---|---|---|---|---|---|---|
| lbs. per Square In. | Inches of Mercury. | lbs. per Square In. | Inches of Mercury. | Deg. Fahr. | | |
| 1 | 2·0355 | −13·7 | −27·886 | 101·99 | 1113·1 | 1043·0 |
| 2 | 4·0710 | −12·7 | −25·851 | 126·27 | 1120·5 | 1026·1 |
| 3 | 6·1065 | −11·7 | −23·815 | 141·62 | 1125·1 | 1015·3 |
| 4 | 8·142 | −10·7 | −21·780 | 153·09 | 1128·6 | 1007·2 |
| 5 | 10·178 | −9·7 | −19·744 | 162·34 | 1131·5 | 1000·8 |
| 6 | 12·213 | −8·7 | −17·709 | 170·14 | 1133·8 | 995·2 |
| 7 | 14·249 | −7·7 | −15·673 | 176·90 | 1135·9 | 990·5 |
| 8 | 16·284 | −6·7 | −13·638 | 182·92 | 1137·7 | 986·2 |
| 9 | 18·320 | −5·7 | −11·602 | 188·33 | 1139·4 | 982·5 |
| 10 | 20·355 | −4·7 | −9·567 | 193·25 | 1140·9 | 979·0 |
| 11 | 22·319 | −3·7 | −7·531 | 197·78 | 1142·3 | 975·8 |
| 12 | 24·426 | −2·7 | −5·496 | 201·98 | 1143·6 | 972·9 |
| 13 | 26·462 | −1·7 | −3·460 | 205·89 | 1144·7 | 970·1 |
| 14 | 28·497 | −0·7 | −1·425 | 209·57 | 1145·8 | 967·5 |
| 14·7 | 29·922 | 0·0 | 0·000 | 212·00 | 1146·6 | 965·8 |
| 15 | 30·533 | 0·3 | 0·611 | 213·03 | 1146·9 | 965·1 |
| 16 | 32·568 | 1·3 | 2·646 | 216·32 | 1147·9 | 962·8 |
| 17 | 34·604 | 2·3 | 4·682 | 219·44 | 1148·9 | 960·6 |
| 18 | 36·639 | 3·3 | 6·717 | 222·40 | 1149·8 | 958·5 |
| 19 | 38·675 | 4·3 | 8·753 | 225·24 | 1150·7 | 956·6 |
| 20 | 40·710 | 5·3 | 10·788 | 227·95 | 1151·5 | 954·6 |
| 21 | 42·746 | 6·3 | 12·824 | 230·55 | 1152·3 | 952·8 |
| 22 | 44·781 | 7·3 | 14·859 | 233·06 | 1153·0 | 951·0 |
| 23 | 46·787 | 8·3 | 15·895 | 235·47 | 1153·7 | 949·2 |
| 24 | 48·852 | 9·3 | 18·930 | 237·79 | 1154·4 | 947·6 |
| 25 | 50·888 | 10·3 | 20·966 | 240·04 | 1155·1 | 946·0 |
| 26 | 52·923 | 11·3 | 23·007 | 242·21 | 1155·8 | 944·6 |
| 27 | 54·972 | 12·3 | 25·043 | 244·32 | 1156·5 | 943·1 |
| 28 | 57·008 | 13·3 | 27·079 | 246·36 | 1157·1 | 941·7 |
| 29 | 59·044 | 14·3 | 29·115 | 248·34 | 1157·7 | 940·3 |
| 30 | 61·080 | 15·3 | 31·143 | 250·27 | 1158·3 | 938·9 |
| 31 | 63·116 | 16·3 | 33·187 | 252·15 | 1158·8 | 937·5 |
| 32 | 65·152 | 17·3 | 35·223 | 253·98 | 1159·4 | 936·3 |
| 33 | 67·188 | 18·3 | 37·239 | 255·76 | 1159·9 | 935·0 |
| 34 | 69·224 | 19·3 | 39·295 | 257·50 | 1160·4 | 933·7 |
| 35 | 71·260 | 20·3 | 41·321 | 259·19 | 1161·0 | 932·6 |
| 36 | 73·296 | 21·3 | 43·367 | 260·85 | 1161·5 | 931·5 |
| 37 | 75·331 | 22·3 | 45·319 | 262·47 | 1162·0 | 930·3 |
| 38 | 77·367 | 23·3 | 47·397 | 264·06 | 1162·5 | 929·2 |
| 39 | 79·403 | 24·3 | 50·463 | 265·61 | 1163·0 | 928·2 |

TABLE SHOWING PROPERTIES OF SATURATED STEAM.—*Yaryan.*—*Continued.*

| Absolute Pressure from Vacuum. | | Above Atmosphere. | | Temperature. | Total Heat in British Units. | Heat of Vaporization or Latent Heat. |
|---|---|---|---|---|---|---|
| lbs. per Square In. | Inches of Mercury. | lbs. per Square In. | Inches of Mercury. | Deg. Fahr. | | |
| 40 | 81·439 | 25·3 | 51·499 | 267·13 | 1163·4 | 927·0 |
| 41 | 83·475 | 26·3 | 53·534 | 268·62 | 1163·9 | 926·0 |
| 42 | 85·511 | 27·3 | 55·583 | 270·08 | 1164·3 | 925·0 |
| 43 | 87·547 | 28·3 | 57·619 | 271·51 | 1164·8 | 924·0 |
| 44 | 89·583 | 29·3 | 59·655 | 272·91 | 1165·2 | 923·0 |
| 45 | 91·619 | 30·3 | 61·691 | 274·29 | 1165·6 | 922·0 |
| 46 | 93·655 | 31·3 | 63·727 | 275·65 | 1166·0 | 921·0 |
| 47 | 95·691 | 32·3 | 65·763 | 276·99 | 1166·4 | 920·1 |
| 48 | 97·727 | 33·3 | 67·799 | 278·30 | 1166·8 | 919·2 |
| 49 | 99·763 | 34·3 | 69·835 | 279·58 | 1167·2 | 918·3 |
| 50 | 101·799 | 35·3 | 71·871 | 280·85 | 1167·6 | 917·4 |
| 55 | 111·98 | 40·3 | 82·050 | 286·89 | 1169·4 | 913·1 |
| 60 | 122·16 | 45·3 | 92·230 | 292·51 | 1171·2 | 909·3 |
| 65 | 132·34 | 50·3 | 102·410 | 297·77 | 1172·7 | 905·5 |
| 70 | 142·52 | 55·3 | 112·59 | 302·71 | 1174·3 | 902·1 |
| 75 | 152·70 | 60·3 | 122·77 | 307·38 | 1175·7 | 898·8 |
| 80 | 162·88 | 65·3 | 132·95 | 311·80 | 1177·0 | 895·6 |
| 85 | 173·06 | 70·3 | 143·13 | 316·02 | 1178·3 | 892·5 |
| 90 | 185·24 | 75·3 | 153·31 | 320·04 | 1179·6 | 889·6 |
| 95 | 193·42 | 80·3 | 163·49 | 323·89 | 1180·7 | 886·7 |
| 100 | 203·06 | 85·3 | 173·67 | 327·58 | 1181·9 | 884·0 |
| 105 | 213·78 | 90·3 | 185·85 | 331·13 | 1182·9 | 881·3 |
| 110 | 223·96 | 95·3 | 194·03 | 334·56 | 1184·0 | 878·8 |
| 115 | 234·14 | 100·3 | 203·67 | 337·86 | 1185·0 | 876·3 |
| 120 | 244·32 | 105·3 | 214·39 | 341·05 | 1186·0 | 874·0 |
| 125 | 254·50 | 110·3 | 224·57 | 344·13 | 1186·9 | 871·7 |
| 130 | 264·68 | 115·3 | 234·75 | 347·12 | 1187·8 | 869·4 |
| 135 | 274·86 | 120·3 | 244·93 | 350·03 | 1188·7 | 867·3 |
| 140 | 285·04 | 125·3 | 255·11 | 352·85 | 1189·5 | 865·1 |
| 145 | 295·22 | 130·3 | 265·29 | 355·59 | 1190·4 | 863·2 |
| 150 | 305·40 | 135·3 | 275·47 | 358·26 | 1191·2 | 861·2 |
| 160 | 325·76 | 145·3 | 295·83 | 363·40 | 1192·8 | 857·4 |
| 170 | 345·82 | 155·3 | 316·19 | 368·29 | 1194·2 | 853·8 |
| 180 | 366·48 | 165·3 | 336·55 | 372·97 | 1195·7 | 850·3 |
| 190 | 386·84 | 175·3 | 356·91 | 377·44 | 1197·1 | 847·0 |
| 200 | 407·20 | 185·3 | 377·27 | 381·73 | 1198·4 | 843·8 |

PROPERTIES OF SATURATED STEAM AT PRESSURE FROM ONE POUND TO 200 POUNDS ON THE SQUARE INCH.

("*Compend. of Mechanical Refrigeration.*")

| Pressure Absolute. | | Heat in Degrees Fahr | | | | | Volume, that of an equal weight of Water at its greatest density being 1. | Weight of one cubic foot in Decimals of a pound. | Specific Gravity, the atmosphere at 32° being 1. |
|---|---|---|---|---|---|---|---|---|---|
| In lbs. on the sq. in. | In inches of Mercury at 32°. | Temperature. | Dif. per lb. | Latent Heat. | Total Heat. | Dif. per lb. | | | |
| 1 | 2·0375 | 102·0° | — | 1,043·05 | 1,145·05 | — | 20,890 | 0·0029 | 0·037 |
| 5 | 10·1875 | 162·37 | 9·26 | 1,001·9 | 1,163·46 | 2·82 | 4,627 | 0·0135 | 0·167 |
| 10 | 20·375 | 193·29 | 4·93 | 979·6 | 1,172·89 | 1·50 | 2,429 | 0·0257 | 0·318 |
| 15 | 30·5625 | 213·07 | 3·47 | 965·85 | 1,178·92 | 1·05 | 1,669 | 0·0373 | 0·463 |
| 20 | 40·75 | 228·0 | 2·8 | 955·5 | 1,183·5 | 0·8 | 1,280 | 0·0487 | 0·604 |
| 25 | 50·9375 | 240·2 | 2·3 | 947·0 | 1,187·2 | 0·7 | 1,042 | 0·0598 | 0·742 |
| 30 | 61·125 | 250·4 | 2·0 | 939·9 | 1,190·3 | 0·6 | 881 | 0·0707 | 0·877 |
| 35 | 71·3125 | 259·3 | 1·7 | 933·7 | 1,193·0 | 0·5 | 764 | 0·0815 | 1·012 |
| 40 | 81·5 | 267·3 | 1·5 | 928·1 | 1,195·4 | 0·4 | 676 | 0·0921 | 1·142 |
| 45 | 91·6875 | 274·4 | 1·4 | 923·2 | 1,197·6 | 0·4 | 608 | 0·1025 | 1·272 |
| 50 | 101·875 | 281·0 | 1·3 | 918·6 | 1,199·6 | 0·4 | 552 | 0·1129 | 1·402 |
| 55 | 112·0625 | 287·1 | 1·2 | 914·4 | 1,201·5 | 0·4 | 506 | 0·1232 | 1·529 |
| 60 | 122·25 | 292·7 | 1·1 | 910·5 | 1,203·2 | 0·3 | 467 | 0·1335 | 1·654 |
| 65 | 132·4375 | 298·0 | 1·1 | 906·8 | 1,204·8 | 0·3 | 434 | 0·1436 | 1·779 |

PROPERTIES OF SATURATED STEAM AT PRESSURE FROM ONE POUND TO 200 POUNDS ON THE SQUARE INCH.—(*Continued.*)

("*Compend. of Mechanical Refrigeration.*")

| Pressure Absolute. | | Heat in Degrees Fahr. | | | | | Volume, that of an equal weight of Water at its greatest density being 1. | Weight of one cubic foot in Decimals of a pound. | Specific Gravity, the atmosphere at 32° being 1. |
|---|---|---|---|---|---|---|---|---|---|
| In lbs. on the sq. in. | In inches of Mercury at 32°. | Temperature. | | Latent Heat. | Total Heat. | | | | |
| | | | Dif. per lb. | | | Dif. per lb. | | | |
| 70 | 142·625 | 302·9° | 1·0 | 903·4 | 1,206·3 | 0·3 | 406 | 0·1536 | 1·904 |
| 75 | 152·8125 | 307·5 | 0·9 | 900·3 | 1,207·8 | 0·3 | 381 | 0·1636 | 2·029 |
| 80 | 163·0 | 312·0 | 0·9 | 897·1 | 1,209·1 | 0·2 | 359 | 0·1736 | 2·151 |
| 85 | 173·1675 | 316·1 | 0·8 | 894·3 | 1,210·4 | 0·3 | 340 | 0·1833 | 2·271 |
| 90 | 183·375 | 320·2 | 0·8 | 891·4 | 1,211·6 | 0·2 | 323 | 0·1939 | 2·391 |
| 95 | 193·5625 | 324·1 | 0·8 | 888·7 | 1,212·8 | 0·3 | 307 | 0·2030 | 2·511 |
| 100 | 203·75 | 327·8 | 0·7 | 886·1 | 1,213·9 | 0·2 | 293 | 0·2127 | 2·631 |
| 105 | 213·9375 | 331·3 | 0·7 | 883·7 | 1,215·0 | 0·2 | 281 | 0·2224 | 2·751 |
| 110 | 224·135 | 334·6 | 0·6 | 881·4 | 1,216·0 | 0·2 | 269 | 0·2319 | 2·871 |
| 115 | 234·3125 | 338·0 | 0·6 | 879·0 | 1,217·0 | 0·2 | 259 | 0·2410 | 2·990 |
| 120 | 244·5 | 341·1 | 0·6 | 876·9 | 1,218·0 | 0·2 | 249 | 0·2503 | 3·105 |
| 125 | 254·6875 | 344·2 | 0·6 | 874·7 | 1,218·9 | 0·2 | 239 | 0·2598 | 3·227 |
| 130 | 264·875 | 347·2 | 0·6 | 872·6 | 1,219·8 | 0·2 | 231 | 0·2693 | 3·347 |
| 135 | 275·0625 | 350·0 | 0·5 | 870·7 | 1,220·7 | 0·1 | 223 | 0·2788 | 3·467 |

PROPERTIES OF SATURATED STEAM AT PRESSURE FROM ONE POUND TO 200 POUNDS ON THE SQUARE INCH.—(*Continued.*)

("*Compend. of Mechanical Refrigeration.*")

| Pressure Absolute. | | Heat in Degrees Fahr. | | | | | Volume, that of an equal weight of Water at its greatest density being 1. | Weight of one cubic foot in Decimals of a pound. | Specific Gravity, the atmosphere at 32° being 1. |
|---|---|---|---|---|---|---|---|---|---|
| In lbs. on the sq. in. | In inches of Mercury at 32°. | Temperature. | Dif. per lb. | Latent Heat. | Total Heat. | Dif. per lb. | | | |
| 140 | 285·25 | 352·9° | 0·6 | 868·6 | 1.221·5 | 0·1 | 216 | 0·2883 | 3·582 |
| 145 | 295·4375 | 355·6 | 0·6 | 866·8 | 1,222·4 | 0·2 | 209 | 0·2978 | 3·697 |
| 150 | 305·625 | 358·3 | 0·5 | 864·9 | 1,223·2 | 0·2 | 203 | 0·3073 | 3·809 |
| 155 | 315·8125 | 360·9 | 0·5 | 863·1 | 1,224·0 | 0·2 | 196 | 0·3168 | 3·927 |
| 160 | 326·0 | 363·4 | 0·5 | 861·4 | 1,224·8 | 0·2 | 191 | 0·3263 | 4·042 |
| 165 | 336·1875 | 365·9 | 0·5 | 859·7 | 1,225·6 | 0·2 | 186 | 0·3353 | 4·157 |
| 170 | 346·375 | 368·2 | 0·4 | 858·1 | 1,226·3 | 0·2 | 181 | 0·3443 | 4·270 |
| 175 | 356·5625 | 370·6 | 0·5 | 856·4 | 1,227·0 | 0·1 | 176 | 0·3533 | 4·383 |
| 180 | 366·75 | 372·9 | 0·4 | 854·8 | 1,227·7 | 0·1 | 172 | 0·3623 | 4·495 |
| 185 | 376·9375 | 375·3 | 0·5 | 853·1 | 1,228·4 | 0·1 | 168 | 0·3713 | 4·607 |
| 190 | 387·125 | 377·5 | 0·4 | 851·6 | 1,229·1 | 0·1 | 164 | 0·3800 | 4·720 |
| 195 | 396·3125 | 379·7 | 0·4 | 850·1 | 1,229·8 | 0·2 | 160 | 0·3888 | 4·832 |
| 200 | 407·5 | 381·7 | 0·3 | 848·6 | 1,230·3 | 0·1 | 157 | 0·3973 | 4·945 |

## HEAT OF COMBUSTION OF VARIOUS FUELS.

| Fuel. | Air Chemically Consumed per lb of Fuel. | | Total Heat of Combustion of 1 lb. of Fuel | Equivalent Evaporative Power, from and at 212° F., Water per lb. of Fuel. |
|---|---|---|---|---|
| | lbs. | Cub Ft at 62° F | Units. | lbs. |
| Asphalt .. .. .. | 11·85 | 156 | 17,040 | 17·64 |
| Coal of average composition | 10·7 | 140 | 14,700 | 15·22 |
| Coke .. .. .. .. | 10·81 | 142 | 13,548 | 14·02 |
| Lignite .. .. .. | 8·85 | 146 | 13,108 | 13·57 |
| Peat, desiccated .. .. | 7·52 | 99 | 12,279 | 12·71 |
| Peat, 30 per cent. moisture.. | 5·24 | 69 | 8,260 | 9·53 |
| Peat charcoal, desiccated .. | 9·9 | 130 | 12,3[illegible] | 12·76 |
| Petroleum .. .. .. | 14·33 | 188 | 20,411 | 21·13 |
| Petroleum oils .. .. | 17·93 | 2[illegible] | 27,531 | 28·50 |
| Straw .. .. .. .. | 4·26 | 56 | 8,144 | 8·43 |
| Wood charcoal, desiccated .. | 9·51 | 125 | 13,006 | 13·46 |
| Wood, desiccated .. .. | 6·09 | 80 | 10,974 | 11·36 |
| Wood, 25 per cent. moisture | 4·57 | 60 | 7,951 | 8·20 |
| Coal gas, per cubic foot at 62° F. .. .. .. | — | — | 630 | 0·70 |

## PERCENTAGES, HANDY RULE.

Regard percentages as a decimal fraction, and with it multiply the whole number wanted. For example, 16 per cent. of 80 is 80 × 0·16 = 12·8.

## SPECIFIC HEAT OF WATER AT VARIOUS TEMPERATURES.

| Temperature. Deg. Fahr. | Specific Heat. | Units of Heat required to raise 1 lb. of Water from 32° F. to given Temperature. | Temperature. Deg. Fahr. | Specific Heat. | Units of Heat required to raise 1 lb. of Water from 32° F. to given Temperature. |
|---|---|---|---|---|---|
| 32° | 1·0000 | 0·000 | 248° | 1·0177 | 217·449 |
| 50 | 1·0005 | 18·004 | 266 | 1·0204 | 235·791 |
| 68 | 1·0012 | 36·018 | 284 | 1·0232 | 254·187 |
| 86 | 1·0020 | 54·047 | 302 | 1·0262 | 272·628 |
| 104 | 1·0030 | 72·090 | 320 | 1·0294 | 291·132 |
| 122 | 1·0042 | 90·157 | 338 | 1·0328 | 309·690 |
| 140 | 1·0056 | 108·247 | 356 | 1·0364 | 328·320 |
| 158 | 1·0072 | 126·378 | 374 | 1·0401 | 347·004 |
| 176 | 1·0089 | 144·508 | 392 | 1·0440 | 365·760 |
| 194 | 1·0109 | 162·686 | 410 | 1·0481 | 384·588 |
| 212 | 1·0130 | 180·900 | 428 | 1·0524 | 403·488 |
| 230 | 1·0153 | 199·152 | 446 | 1·0568 | 422·478 |

## SPECIFIC HEAT OF METALS, ETC.

| METALS. | | STONES (*contd.*) | |
|---|---|---|---|
| Antimony | 0·0507 | Chalk | 0·2148 |
| Bismuth | 0·0308 | Quicklime | 0·2169 |
| Brass | 0·0939 | Magnesian limestone | 0·2174 |
| Copper | 0·0951 | | |
| Cymbal metal | 0·086 | | |
| Gold | 0·0324 | CARBONACEOUS. | |
| Iridium | 0·1887 | Coal | 0·2411 |
| Iron, cast | 0·1298 | Charcoal | 0·2415 |
| ,, wrought | 0·1138 | Cannel coke | 0·2031 |
| Lead | 0·0314 | Coke of pit coal | 0·2008 |
| Manganese | 0·1441 | Anthracite | 0·2017 |
| Mercury, solid | 0·0319 | Graphite, natural | 0·2019 |
| ,, liquid | 0·0333 | ,, of blast furnaces | 0·197 |
| Nickel | 0·1086 | | |
| Platinum, sheet | 0·0324 | | |
| ,, spongy | 0·0329 | SUNDRY. | |
| Silver | 0·0570 | | |
| Steel | 0·1165 | Glass | 0·1977 |
| Tin | 0·0569 | Ice | 0·504 |
| Zinc | 0·0959 | Phosphorus | 0·2503 |
| | | Soda | 0·2311 |
| STONES. | | Sulphate of lead | 0·0872 |
| Brickwork & masonry | 0·20 | ,, of lime | 0·1966 |
| Marble | 0·2129 | Sulphur | 0·2026 |

## Specific Heat of Liquids.

| | | | |
|---|---|---|---|
| Alcohol .. .. | 0·6588 | Turpentine .. .. | 0·4160 |
| Benzine .. .. | 0·3932 | Vinegar .. .. | 0·9200 |
| Mercury .. .. | 0·0333 | Water at 32° F. .. | 1·0000 |
| Olive oil .. .. | 0·3096 | „ 212° F. .. | 1·0130 |
| Sulphuric acid .. | | „ 32° to 212° F. | 1·0050 |
| Density, 1·87 .. | 0·3346 | Wood spirit .. .. | 0·6009 |
| „ 1·30 .. | 0·6614 | Proof spirit .. .. | 0·973 |

## Specific Heat of Gases.

| For Equal Weights. (Water = 1.) | At Constant Pressure. | At Constant Volume. |
|---|---|---|
| Air .. .. .. .. .. | 0·2377 | 0·1688 |
| Carbonic acid ($CO_2$) .. .. .. | 0·2164 | 0·1714 |
| „ oxide (CO) .. .. .. | 0·2479 | 0·1768 |
| Hydrogen .. .. .. .. | 3·4046 | 2·4096 |
| Light carburetted hydrogen .. .. | 0·5929 | 0·4683 |
| Nitrogen .. .. .. .. | 0·2440 | 0·1740 |
| Oxygen.. .. .. .. .. | 0·2182 | 0·1559 |
| Steam, saturated .. .. .. | — | 0·3050 |
| Steam gas .. .. .. .. | 0·4750 | 0·3700 |
| Sulphurous acid .. .. .. | 0·1553 | 0·1246 |

## British Thermal Unit, or Heat Unit.

Amount of heat necessary to raise the temperature of 1 lb. of water 1° by the Fahr. scale when at 39·4° (temp. of max. density). Mech. eq. 778 ft.-lbs.

## French Calorie, English Equivalent.

Unit of heat used on the Continent with the metrical system. Amount of heat required to raise 1 kilo. of water through 1° Cent. B.T.U. × 0·252 = calorie. Calories × 3·968 = B.T.U.

## Loss of Pressure by Friction of Compressed Air in Pipes.

*F. A. Halsey.*

| Diameter of Pipe. | Cubic feet of Free Air compressed to a Gauge Pressure of 60 lbs. per Square Inch and passing through the Pipe per Minute. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 125 | 150 | 200 | 250 | 300 | 400 | 600 |
| | Loss of Pressure in Pounds per Square Inch for each 1,000 Feet of Straight Pipe. | | | | | | | | | |
| ins. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 1 | 10·40 | | | | | | | | | |
| 1¼ | 2·63 | 5·90 | | | | | | | | |
| 1½ | 1·22 | 2·75 | 4·89 | 7·65 | 11·00 | | | | | |
| 2 | ·35 | ·79 | 1·41 | 2·20 | 3·17 | 5·64 | 8·78 | | | |
| 2½ | ·14 | ·32 | ·57 | ·90 | 1·29 | 2·30 | 3·58 | 5·18 | 9·20 | |
| 3 | | ·11 | ·20 | ·31 | ·44 | ·78 | 1·23 | 1·77 | 3·14 | 7·05 |
| 3½ | | | | ·15 | ·21 | ·38 | ·59 | ·85 | 1·51 | 3·40 |
| 4 | | | | | | ·20 | ·31 | ·45 | ·80 | 1·81 |
| 5 | | | | | | | ·10 | ·15 | ·26 | ·59 |
| 6 | | | | | | | | | | ·23 |

Friction of Air in Tubes.—*Unwin, "Min. Proceedings Inst. C.E."*

$k$ = coefficient of friction $= \frac{a}{v} + b$, $a$ and $b$ being constants, and

$v$ = velocity of air feet per second.

| | | | | | | |
|---|---|---|---|---|---|---|
| Diameter of tube, ft. | 1·64 | 1·07 | ·83 | ·338 | ·266 | ·164 |
| Value of $a$ . . | ·00129 | ·00972 | ·01525 | ·03604 | ·0379 | ·04518 |
| " $b$ . . | ·00483 | ·0064 | ·00704 | ·00941 | ·00959 | ·01167 |
| " $k$ if $v$=100 | ·00484 | ·0065 | ·00719 | ·00719 | ·00997 | ·01212 |

## Power Required for Refrigeration.

For running the compressor, pumping both water and brine, and driving fans 1½ horse-power will be required for each ton of refrigeration.

### COEFFICIENTS FOR EFFLUX OF AIR FROM ORIFICES.
*(Molesworth).*

| | |
|---|---|
| Vena contracta . . . . . . | 0·98 |
| Conical converging . . . . . | 0·9 |
| Cylindrical rounded at ends . . . | 0·9 |
| Cylindrical throughout . . . . | 0·8 |
| Thin plates . . . . . . | 0·6 |

### CENTRIFUGAL FANS.—*Molesworth.*

D = Diameter of fan.
V = Velocity of tips of fan in feet per second.
P = Pressure in lbs. per square inch.

$$V = \sqrt{P \times 97300}.$$

$$P = \frac{V^2}{97300}$$

### POWER REQUIRED FOR FANS.—*Molesworth.*

P = Pressure of blast in lbs. per square inch.
A = Area of the sum of the tuyeres in square inches.
V = Velocity of tips of fan in feet per second.
HP = Indicated horse-power required.

$$HP = 0·000016\ V^2\ A\ P.$$

### PROPORTIONS OF FANS.—*Molesworth.*

Length of vanes $= \frac{D}{4}$. Width of vanes $= \frac{D}{4}$.

Diameter of inlet $= \frac{D}{2}$. Eccentricity of fan $= \frac{D}{10}$.

Length of spindle journal = 4 diameters of spindle.

## Hydraulic Ram, Proportions of the Supply Pipes and Delivery Pipes to the Number of Gallons.—(*Hutton.*)

| | | | | | |
|---|---|---|---|---|---|
| Number of gallons to be raised in 24 hours . . . | 500 | 1,000 | 2,500 | 4,000 | 6,000 |
| Diameter of fall or supply pipe, in inches . . . . | $1\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | 3 | 4 |
| Diameter of rising main or delivery pipe, in inches . | $\frac{3}{4}$ | 1 | $1\frac{1}{2}$ | 2 | 2 |

## Efficiency of Hydraulic Rams.—(*Hutton.*)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of times the height to which the water to be raised is contained in the fall . | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 25 |
| Efficiency per cent. . . | 75 | 72 | 68 | 62 | 57 | 53 | 48 | 43 | 38 | 35 | 32 | 28 | 23 | 17 | 15 | 12 | 0 |

## Power required to drive Centrifugal Pumps.

| Diameter of suction and delivery pipes in inches. | Quantity of water delivered per minute, in gallons. | Horse-power required for every foot in height the water is raised. |
|---|---|---|
| 1 | 16 | 0·01 |
| 2 | 50 | 0·02 |
| 3 | 100 | 0·05 |
| 4 | 200 | 0·08 |
| 5 | 300 | 0·16 |
| 6 | 500 | 0·25 |
| 7 | 700 | 0·35 |
| 8 | 800 | 0·40 |
| 9 | 1,000 | 0·50 |
| 10 | 1,500 | 0·75 |
| 11 | 1,800 | 1·0 |
| 12 | 2,000 | 1·01 |
| 13 | 2,300 | 1·08 |
| 14 | 2,500 | 1·20 |
| 15 | 3,000 | 1·31 |
| 16 | 3,500 | 1·60 |
| 17 | 3,800 | 1·75 |
| 18 | 4,200 | 2·0 |

**Table of Power required to raise Water from Deep Wells.**—(*Appleby.*)

| | | | | | | |
|---|---|---|---|---|---|---|
| Gallons of water raised per hour. | 200 | 350 | 500 | 650 | 800 | 1,000 |
| Height of lift for one man working on crank, in feet . . . . | 90 | 52 | 36 | 28 | 22 | 18 |
| Height of lift for one donkey working on gin, in feet . . . | 180 | 102 | 72 | 56 | 45 | 36 |
| Height of lift for one horse working on gin, in feet . . . . | 630 | 357 | 252 | 196 | 154 | 126 |
| Height of lift for one horse-power steam-engine, in feet . . . . | 990 | 561 | 396 | 308 | 242 | 198 |

***Table giving Quantity of Water discharged per Minute by Barrel Pumps.***—(*Hutton.*)

| Diam. of pump. | Length of stroke. | Single barrel. | | Double barrel. | | Treble barrel. | |
|---|---|---|---|---|---|---|---|
| | | 30 strokes per min. | 40 strokes per min. | 30 strokes per min. | 40 strokes per min. | 30 strokes per min. | 40 strokes per min. |
| Inches. | Inches. | Galls. | Galls. | Galls. | Galls. | Galls. | Galls. |
| 1½ | 9 | 1¾ | 2¼ | 3½ | 4½ | 4½ | 6¾ |
| 2 | 9 | 3 | 4 | 6 | 8 | 9 | 12 |
| 2½ | 9 | 4¾ | 6¼ | 9½ | 12 | 14 | 19 |
| 3 | 9 | 6¾ | 9 | 13¾ | 18 | 20 | 27 |
| 3½ | 9 | 9¼ | 12½ | 18¾ | 25 | 28 | 37 |
| 4 | 9 | 12¼ | 16 | 24½ | 32 | 36 | 48 |
| 4½ | 9 | 15½ | 20¾ | 32 | 42 | 46 | 62 |
| 5 | 9 | 19 | 25½ | 38 | 50 | 57 | 76 |
| 5½ | 9 | 23¼ | 32 | 46½ | 62 | 69 | 92 |
| 6 | 9 | 27½ | 37 | 55 | 73 | 82 | 110 |
| 2 | 10 | 3½ | 4½ | 6 | 9 | 10 | 13 |
| 2½ | 10 | 5¼ | 7 | 10 | 14 | 15 | 22 |
| 3 | 10 | 7½ | 10 | 15 | 20 | 22 | 30 |
| 3½ | 10 | 10½ | 13¾ | 20 | 27 | 32 | 42 |
| 4 | 10 | 13½ | 18 | 27 | 36 | 40 | 54 |
| 4½ | 10 | 17 | 23 | 34 | 45 | 52 | 68 |
| 5 | 10 | 22 | 28 | 42 | 56 | 63 | 84 |
| 5½ | 10 | 25½ | 34 | 51 | 68 | 77 | 102 |
| 6 | 10 | 30½ | 40 | 62 | 82 | 92 | 122 |
| 2 | 12 | 4 | 5 | 8 | 10 | 12 | 16 |
| 2½ | 12 | 6¼ | 8 | 12 | 17 | 19 | 25 |
| 3 | 12 | 9 | 12 | 18 | 24 | 27 | 36 |
| 3½ | 12 | 12½ | 16 | 24 | 33 | 37 | 50 |
| 4 | 12 | 16¼ | 22 | 32 | 43 | 49 | 65 |
| 4½ | 12 | 20½ | 27 | 42 | 55 | 62 | 82 |
| 5 | 12 | 25¼ | 33 | 50 | 68 | 76 | 100 |
| 5½ | 12 | 30¾ | 42 | 62 | 82 | 92 | 123 |
| 6 | 12 | 36½ | 49 | 73 | 97 | 110 | 146 |
| 6½ | 12 | 43 | 57 | 86 | 114 | 129 | 172 |
| 7 | 12 | 50 | 66 | 100 | 134 | 149 | 199 |
| 7½ | 12 | 57 | 76 | 114 | 152 | 171 | 229 |
| 8 | 12 | 65 | 87 | 130 | 174 | 195 | 262 |
| 9 | 12 | 82 | 110 | 165 | 220 | 246 | 330 |
| 10 | 12 | 102 | 134 | 202 | 268 | 303 | 404 |
| 12 | 12 | 146 | 195 | 294 | 390 | 440 | 588 |

## Diameters, Areas, and Displacements.

*Worthington Pumping Engine Company.*

| Diameter. | Area. | Displacement in Imperial Gallons per foot of Travel. | Diameter. | Area. | Displacement in Imperial Gallons per foot of Travel. | Diameter. | Area. | Displacement in Imperial Gallons per foot of Travel. |
|---|---|---|---|---|---|---|---|---|
| $\frac{1}{8}$ | ·0122 | ·0005 | $7\frac{1}{4}$ | 41·28 | 1·783 | $18\frac{1}{4}$ | 261·5 | 11·297 |
| $\frac{1}{4}$ | ·0490 | ·0021 | $7\frac{1}{2}$ | 44·17 | 1·908 | $18\frac{1}{2}$ | 268·8 | 11·612 |
| $\frac{3}{8}$ | ·1104 | ·0047 | $7\frac{3}{4}$ | 47·17 | 2·037 | $18\frac{3}{4}$ | 276·1 | 11·927 |
| $\frac{1}{2}$ | ·1963 | ·0084 | 8 | 50·26 | 2·171 | 19 | 283·5 | 12·247 |
| $\frac{5}{8}$ | ·3068 | ·0132 | $8\frac{1}{4}$ | 53·45 | 2·309 | $19\frac{1}{4}$ | 291·0 | 12·571 |
| $\frac{3}{4}$ | ·4417 | ·0190 | $8\frac{1}{2}$ | 56·74 | 2·451 | $19\frac{1}{2}$ | 298·6 | 12·900 |
| $\frac{7}{8}$ | ·6013 | ·0259 | $8\frac{3}{4}$ | 60·13 | 2·597 | $19\frac{3}{4}$ | 306·3 | 13·232 |
| 1 | ·7854 | ·0339 | 9 | 63·61 | 2·747 | 20 | 314·1 | 13·569 |
| $1\frac{1}{8}$ | ·0940 | ·0429 | $9\frac{1}{4}$ | 67·20 | 2·903 | $20\frac{1}{2}$ | 330·0 | 14·256 |
| $1\frac{1}{4}$ | 1·227 | ·0530 | $9\frac{1}{2}$ | 70·88 | 3·062 | 21 | 346·3 | 14·960 |
| $1\frac{3}{8}$ | 1·484 | ·0641 | $9\frac{3}{4}$ | 74·66 | 3·225 | $21\frac{1}{2}$ | 363·0 | 15·681 |
| $1\frac{1}{2}$ | 1·767 | ·0763 | 10 | 78·54 | 3·393 | 22 | 380·1 | 16·420 |
| $1\frac{5}{8}$ | 2·073 | ·0895 | $10\frac{1}{4}$ | 82·51 | 3·564 | $22\frac{1}{2}$ | 397·6 | 17·176 |
| $1\frac{3}{4}$ | 2·405 | ·1038 | $10\frac{1}{2}$ | 86·59 | 3·740 | 23 | 415·4 | 17·945 |
| $1\frac{7}{8}$ | 2·761 | ·1192 | $10\frac{3}{4}$ | 90·76 | 3·920 | $23\frac{1}{2}$ | 433·7 | 18·735 |
| 2 | 3·141 | ·1356 | 11 | 95·03 | 4·105 | 24 | 452·3 | 19·539 |
| $2\frac{1}{8}$ | 3·546 | ·1531 | $11\frac{1}{4}$ | 99·40 | 4·294 | $24\frac{1}{2}$ | 471·4 | 20·364 |
| $2\frac{1}{4}$ | 3·976 | ·1717 | $11\frac{1}{2}$ | 103·8 | 4·484 | 25 | 490·8 | 21·202 |
| $2\frac{3}{8}$ | 4·430 | ·1913 | $11\frac{3}{4}$ | 108·4 | 4·682 | $25\frac{1}{2}$ | 510·7 | 22·062 |
| $2\frac{1}{2}$ | 4·908 | ·2120 | 12 | 113·0 | 4·881 | 26 | 530·9 | 22·935 |
| $2\frac{5}{8}$ | 5·411 | ·2337 | $12\frac{1}{4}$ | 117·8 | 5·088 | $26\frac{1}{2}$ | 551·5 | 23·824 |
| $2\frac{3}{4}$ | 5·939 | ·2565 | $12\frac{1}{2}$ | 122·7 | 5·300 | 27 | 572·5 | 24·732 |
| $2\frac{7}{8}$ | 6·491 | ·2804 | $12\frac{3}{4}$ | 127·6 | 5·512 | $27\frac{1}{2}$ | 593·9 | 25·656 |
| 3 | 7·068 | ·3053 | 13 | 132·7 | 5·732 | 28 | 615·7 | 26·598 |
| $3\frac{1}{8}$ | 7·669 | ·3313 | $13\frac{1}{4}$ | 137·8 | 5·952 | $28\frac{1}{2}$ | 637·9 | 27·567 |
| $3\frac{1}{4}$ | 8·295 | ·3583 | $13\frac{1}{2}$ | 143·1 | 6·182 | 29 | 660·5 | 28·533 |
| $3\frac{3}{8}$ | 8·946 | ·3864 | $13\frac{3}{4}$ | 148·4 | 6·410 | $29\frac{1}{2}$ | 683·4 | 29·522 |
| $3\frac{1}{2}$ | 9·621 | ·4156 | 14 | 153·9 | 6·649 | 30 | 706·8 | 30·533 |
| $3\frac{5}{8}$ | 10·32 | ·4458 | $14\frac{1}{4}$ | 159·4 | 6·886 | 31 | 754·8 | 32·607 |
| $3\frac{3}{4}$ | 11·04 | ·4769 | $14\frac{1}{2}$ | 165·1 | 7·132 | 32 | 804·2 | 34·741 |
| $3\frac{7}{8}$ | 11·79 | ·5193 | $14\frac{3}{4}$ | 170·8 | 7·388 | 33 | 855·3 | 36·949 |
| 4 | 12·56 | ·5426 | 15 | 176·7 | 7·633 | 34 | 907·9 | 39·221 |
| $4\frac{1}{4}$ | 14·18 | ·6125 | $15\frac{1}{4}$ | 182·6 | 7·888 | 35 | 962·1 | 41·562 |
| $4\frac{1}{2}$ | 15·90 | ·6868 | $15\frac{1}{2}$ | 188·6 | 8·147 | 36 | 1017·9 | 43·973 |
| $4\frac{3}{4}$ | 17·72 | ·7655 | $15\frac{3}{4}$ | 194·8 | 8·415 | 37 | 1075·2 | 46·448 |
| 5 | 19·63 | ·8480 | 16 | 201·0 | 8·683 | 38 | 1134·1 | 48·993 |
| $5\frac{1}{4}$ | 21·54 | ·9348 | $16\frac{1}{4}$ | 207·3 | 8·955 | 39 | 1194·6 | 51·607 |
| $5\frac{1}{2}$ | 23·75 | 1·026 | $16\frac{1}{2}$ | 213·8 | 9·236 | 40 | 1256·6 | 54·259 |
| $5\frac{3}{4}$ | 25·96 | 1·121 | $16\frac{3}{4}$ | 220·3 | 9·516 | 41 | 1320·3 | 57·037 |
| 6 | 28·27 | 1·221 | 17 | 226·9 | 9·802 | 42 | 1385·4 | 59·849 |
| $6\frac{1}{4}$ | 30·67 | 1·325 | $17\frac{1}{4}$ | 233·7 | 10·095 | 43 | 1452·2 | 62·735 |
| $6\frac{1}{2}$ | 33·18 | 1·433 | $17\frac{1}{2}$ | 240·5 | 10·389 | 44 | 1520·5 | 65·686 |
| $6\frac{3}{4}$ | 35·78 | 1·545 | $17\frac{3}{4}$ | 247·4 | 10·687 | 45 | 1590·4 | 68·688 |
| 7 | 38·48 | 1·662 | 18 | 254·4 | 10·990 | 46 | 1661·9 | 71·794 |

In estimating the capacity of Worthington (and other duplex) Pumps (*i.e.*, the delivery in gallons per minute or per hour) at a given rate of piston speed, it should be noted that they have *two* double-acting water plungers: the capacity, therefore, is double that of any ordinary double-acting pump of same size, or four times as large as a single-acting pump.

## Pressure of Water.

*Worthington Pumping Engine Company.*

The pressure of water in pounds per square inch for every foot in height to 270 ft. By this Table, from the pounds pressure per square inch the feet head is readily obtained, and *vice versâ*.

| Feet Head. | Pressure per sq. in. | Feet Head. | Pressure per sq. in. | Feet Head. | Pressure per sq. in. | Feet Head. | Pressure per sq. in. | Feet Head. | Pressure per sq. in. | Feet Head. | Pressure per sq. in. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0·43 | 46 | 19·92 | 91 | 39·42 | 136 | 58·91 | 181 | 78·40 | 226 | 97.90 |
| 2 | 0·86 | 47 | 20·35 | 92 | 39·85 | 137 | 59·34 | 182 | 78·84 | 227 | 98·33 |
| 3 | 1·30 | 48 | 20·79 | 93 | 40·28 | 138 | 59·77 | 183 | 79·27 | 228 | 98·76 |
| 4 | 1·73 | 49 | 21·22 | 94 | 40·72 | 139 | 60·21 | 184 | 79·70 | 229 | 99·20 |
| 5 | 2·16 | 50 | 21·65 | 95 | 41·15 | 140 | 60·64 | 185 | 80·14 | 230 | 99·63 |
| 6 | 2·59 | 51 | 22·09 | 96 | 41·58 | 141 | 61·07 | 186 | 80·57 | 231 | 100·06 |
| 7 | 3·03 | 52 | 22·52 | 97 | 42·01 | 142 | 61·51 | 187 | 81·00 | 232 | 100·49 |
| 8 | 3·46 | 53 | 22·95 | 98 | 42·45 | 143 | 61·94 | 188 | 81·43 | 233 | 100·93 |
| 9 | 3·89 | 54 | 23·39 | 99 | 42·83 | 144 | 62·37 | 189 | 81·87 | 234 | 101·36 |
| 10 | 4·33 | 55 | 23·82 | 100 | 43·31 | 145 | 62·81 | 190 | 82·30 | 235 | 101·79 |
| 11 | 4·76 | 56 | 24·26 | 101 | 43·75 | 146 | 63·24 | 191 | 82·73 | 236 | 102·23 |
| 12 | 5·20 | 57 | 24·69 | 102 | 44·18 | 147 | 63·67 | 192 | 83·17 | 237 | 102·66 |
| 13 | 5·63 | 58 | 25·12 | 103 | 44·61 | 148 | 64·10 | 193 | 83·60 | 238 | 103·09 |
| 14 | 6·06 | 59 | 25·55 | 104 | 45·05 | 149 | 64·54 | 194 | 84·03 | 239 | 103·53 |
| 15 | 6·49 | 60 | 25·99 | 105 | 45·48 | 150 | 64·97 | 195 | 84·47 | 240 | 103·96 |
| 16 | 6·93 | 61 | 26·42 | 106 | 45·91 | 151 | 65·49 | 196 | 84·90 | 241 | 104·39 |
| 17 | 7·36 | 62 | 26·85 | 107 | 46·34 | 152 | 65·84 | 197 | 85·33 | 242 | 104·83 |
| 18 | 7·79 | 63 | 27·29 | 108 | 46·78 | 153 | 66·27 | 198 | 85·76 | 243 | 105·26 |
| 19 | 8·22 | 64 | 27·72 | 109 | 47·21 | 154 | 66·70 | 199 | 86·20 | 244 | 105·69 |
| 20 | 8·66 | 65 | 28·15 | 110 | 47·64 | 155 | 67·14 | 200 | 86·63 | 245 | 106·13 |
| 21 | 9·09 | 66 | 28·58 | 111 | 48·08 | 156 | 67·57 | 201 | 87·07 | 246 | 106·56 |
| 22 | 9·53 | 67 | 29·02 | 112 | 48·51 | 157 | 68·00 | 202 | 87·50 | 247 | 106·99 |
| 23 | 9·96 | 68 | 29·45 | 113 | 48·94 | 158 | 68·43 | 203 | 87·93 | 248 | 107·43 |
| 24 | 10·39 | 69 | 29·88 | 114 | 49·38 | 159 | 68·87 | 204 | 88·36 | 249 | 107·86 |
| 25 | 10·82 | 70 | 30·32 | 115 | 49·81 | 160 | 69·31 | 205 | 88·80 | 250 | 108·29 |
| 26 | 11·26 | 71 | 30·75 | 116 | 50·24 | 161 | 69·74 | 206 | 89·23 | 251 | 108·73 |
| 27 | 11·69 | 72 | 31·18 | 117 | 50·68 | 162 | 70·17 | 207 | 89·66 | 252 | 109·16 |
| 28 | 12·12 | 73 | 31·62 | 118 | 51·11 | 163 | 70·61 | 208 | 90·10 | 253 | 109·59 |
| 29 | 12·55 | 74 | 32·05 | 119 | 51·54 | 164 | 71·04 | 209 | 90·53 | 254 | 110·03 |
| 30 | 12·99 | 75 | 32·48 | 120 | 51·98 | 165 | 71·47 | 210 | 90·96 | 255 | 110·46 |
| 31 | 13·42 | 76 | 32·92 | 121 | 52·41 | 166 | 71·91 | 211 | 91·39 | 256 | 110·89 |
| 32 | 13·86 | 77 | 33·35 | 122 | 52·84 | 167 | 72·34 | 212 | 91·83 | 257 | 111·32 |
| 33 | 14·29 | 78 | 33·78 | 123 | 53·28 | 168 | 72·77 | 213 | 92·26 | 258 | 111·76 |
| 34 | 14·72 | 79 | 34·21 | 124 | 53·71 | 169 | 73·20 | 214 | 92·69 | 259 | 112·19 |
| 35 | 15·16 | 80 | 34·65 | 125 | 54·15 | 170 | 73·64 | 215 | 93·13 | 260 | 112·62 |
| 36 | 15·59 | 81 | 35·08 | 126 | 54·58 | 171 | 74·07 | 216 | 93·56 | 261 | 113·06 |
| 37 | 16·02 | 82 | 35·52 | 127 | 55·01 | 172 | 74·50 | 217 | 93·99 | 262 | 113·49 |
| 38 | 16·45 | 83 | 35·95 | 128 | 55·44 | 173 | 74·94 | 218 | 94·43 | 263 | 113·92 |
| 39 | 16·89 | 84 | 36·39 | 129 | 55·88 | 174 | 75·37 | 219 | 94·86 | 264 | 114·36 |
| 40 | 17·32 | 85 | 36·82 | 130 | 56·31 | 175 | 75·80 | 220 | 95·30 | 265 | 114·79 |
| 41 | 17·75 | 86 | 37·25 | 131 | 56·74 | 176 | 76·23 | 221 | 95·73 | 266 | 115·22 |
| 42 | 18·19 | 87 | 37·68 | 132 | 57·18 | 177 | 76·67 | 222 | 96·16 | 267 | 115·66 |
| 43 | 18·62 | 88 | 38·12 | 133 | 57·61 | 178 | 77·10 | 223 | 96·59 | 268 | 116·09 |
| 44 | 19·05 | 89 | 38·55 | 134 | 58·04 | 179 | 77·53 | 224 | 97·03 | 269 | 116·52 |
| 45 | 19·49 | 90 | 39·98 | 135 | 58·48 | 180 | 77·97 | 225 | 97·46 | 270 | 116·96 |

## DIMENSIONS, ETC., OF STANDARD WROUGHT-IRON PIPES.

| Nominal size in inches. | Inside diam. in inches. | Inside diam. extra strong in inches. | Inside diam. extra double strong in ins. | External diam. in inches. | Internal diam. in inches. | External circumference in inches. | Length in feet per square foot outside surface. | Weight per foot in lbs. | Number of threads per inch. |
|---|---|---|---|---|---|---|---|---|---|
| 1/8 | 0·27 | 0·20 | — | 0·40 | 0·0572 | 1·272 | 9·44 | 0·24 | 27 |
| 1/4 | 0·36 | 0·29 | — | 0·54 | 0·1041 | 1·696 | 7·075 | 0·42 | 18 |
| 3/8 | 0·49 | 0·42 | — | 0·67 | 0·1916 | 2·121 | 5·657 | 0·56 | 18 |
| 1/2 | 0·62 | 0·54 | 0·24 | 0·84 | 0·3048 | 2·652 | 4·502 | 0·85 | 14 |
| 3/4 | 0·82 | 0·73 | 0·42 | 1·05 | 0·5333 | 3·299 | 3·637 | 1·12 | 14 |
| 1 | 1·04 | 0·95 | 0·58 | 1·31 | 0·8627 | 4·134 | 2·903 | 1·67 | 11½ |
| 1¼ | 1·38 | 1·27 | 0·88 | 1·66 | 1·496 | 5·215 | 2·301 | 2·25 | 11½ |
| 1½ | 1·61 | 1·49 | 1·08 | 1·90 | 2·038 | 5·969 | 2·01 | 2·69 | 11½ |
| 2 | 2·06 | 1·93 | 1·49 | 2·37 | 3·355 | 7·461 | 1·611 | 3·66 | 11½ |
| 2½ | 2·46 | 2·31 | 1·75 | 2·87 | 4·783 | 9·032 | 1·328 | 5·77 | 8 |
| 3 | 3·06 | 2·89 | 2·28 | 3·50 | 7·388 | 10·996 | 1·091 | 7·54 | 8 |
| 3½ | 3·54 | 3·35 | 2·71 | 4·00 | 9·887 | 12·566 | 0·955 | 9·05 | 8 |
| 4 | 4·02 | 3·81 | 3·13 | 4·50 | 12·730 | 14·137 | 0·849 | 10·72 | 8 |
| 5 | 5·04 | — | — | 5·56 | 19·990 | 17·475 | 0·629 | 14·56 | 8 |
| 6 | 6·00 | — | — | 6·62 | 28·889 | 20·813 | 0·577 | 18·77 | 8 |
| 7 | 7·02 | — | — | 7·62 | 38·737 | 23·954 | 0·505 | 23·41 | 8 |
| 8 | 7·98 | — | — | 8·62 | 50·039 | 27·096 | 0·444 | 28·35 | 8 |
| 9 | 9·00 | — | — | 9·68 | 63·633 | 30·433 | 0·394 | 34·07 | 8 |
| 10 | 10·01 | — | — | 10·75 | 78·838 | 33·772 | 0·355 | 40·64 | 8 |

### STRENGTH OF ICE.

Ice of a thickness of 1½ inch will support a man; 4 inches in thickness will support cavalry; 5 inches in thickness will support an 84-pound cannon; 10 inches in thickness will support a multitude; 18 inches in thickness will support a railroad train.

## Friction in Pipes.

**Friction loss in pounds pressure for each 100 feet in length of cast-iron pipe discharging the stated quantities per minute.**—(*G. A. Ellis, C.E.*)

| Imperial gallons. | Sizes of pipes, inside diameters. | | | | | | | | | | | | | | | U.S. gallons. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ¾" | 1" | 1¼" | 1½" | 2" | 2¼" | 3" | 4" | 6" | 8" | 10" | 12" | 14" | 16" | 18" | |
| 4 | 3·3 | 0·84 | 0·31 | 0·12 | | | | | | | | | | | | 5 |
| 8 | 13·0 | 3·16 | 1·05 | 0·47 | 0·12 | | | | | | | | | | | 10 |
| 12 | 28·7 | 6·98 | 2·38 | 0·97 | 0·27 | | | | | | | | | | | 15 |
| 16 | 50·4 | 12·30 | 4·07 | 1·66 | 0·42 | | | | | | | | | | | 20 |
| 20 | 78·0 | 19·00 | 6·40 | 2·62 | 0·67 | 0·21 | 0·10 | | | | | | | | | 25 |
| 25 | | 27·50 | 9·15 | 3·75 | 0·91 | 0·30 | 0·12 | | | | | | | | | 30 |
| 29 | | 37·00 | 12·4 | 5·05 | 1·26 | 0·42 | 0·14 | | | | | | | | | 35 |
| 33 | | 48·00 | 16·1 | 6·52 | 1·60 | 0·51 | 0·17 | | | | | | | | | 40 |
| 37 | | | 20·2 | 8·15 | 2·01 | 0·62 | 0·27 | | | | | | | | | 45 |
| 41 | | | 24·9 | 10·00 | 2·44 | 0·81 | 0·35 | 0·09 | | | | | | | | 50 |
| 62 | | | 56·1 | 22·40 | 5·32 | 1·80 | 0·74 | 0·21 | | | | | | | | 75 |
| 83 | | | | 39·00 | 9·46 | 3·20 | 1·31 | 0·35 | 0·05 | | | | | | | 100 |
| 103 | | | | 48·10 | 14·9 | 4·89 | 1·99 | 0·51 | 0·07 | | | | | | | 125 |
| 124 | | | | | 21·2 | 7·00 | 2·85 | 0·69 | 0·10 | 0·02 | | | | | | 150 |
| 145 | | | | | 28·1 | 9·46 | 3·85 | 0·95 | 0·14 | 0·03 | | | | | | 175 |
| 166 | | | | | 37·5 | 12·47 | 5·02 | 1·22 | 0·17 | 0·05 | 0·01 | | | | | 200 |
| 207 | | | | | 47·7 | 19·56 | 7·76 | 1·89 | 0·26 | 0·07 | 0·03 | | | | | 250 |
| 249 | | | | | | 28·06 | 11·20 | 2·66 | 0·37 | 0·09 | 0·04 | 0·005 | | | | 300 |
| 290 | | | | | | 33·41 | 15·20 | 3·65 | 0·50 | 0·11 | 0·05 | 0·007 | | | | 350 |
| 332 | | | | | | 42·96 | 19·50 | 4·73 | 0·65 | 0·15 | 0·06 | 0·01 | | | | 400 |
| 373 | | | | | | | 25·00 | 6·01 | 0·81 | 0·20 | 0·08 | 0·02 | | | | 450 |
| 415 | | | | | | | 30·80 | 7·43 | 0·96 | 0·25 | 0·09 | 0·04 | 0·017 | 0·009 | 0·005 | 500 |
| 621 | | | | | | | | 14·32 | 2·21 | 0·53 | 0·18 | 0·08 | 0·030 | 0·019 | 0·011 | 750 |
| 830 | | | | | | | | | 3·88 | 0·04 | 0·32 | 0·13 | 0·062 | 0·036 | 0·020 | 1,000 |
| 1,037 | | | | | | | | | | 1·46 | 0·4[illegible] | 0·20 | 0·091 | 0·046 | 0·028 | 1,250 |
| 1,245 | | | | | | | | | | 2·04 | 0·70 | 0·29 | 0·135 | 0·071 | 0·040 | 1,500 |
| 1,450 | | | | | | | | | | | 0·95 | 0·38 | 0·181 | 0·095 | 0·054 | 1,750 |
| 1,660 | | | | | | | | | | | 1·23 | 0·49 | 0·234 | 0·123 | 0·071 | 2,000 |
| 1,867 | | | | | | | | | | | | 0·63 | 0·297 | 0·153 | 0·086 | 2,250 |
| 2,075 | | | | | | | | | | | | 0·77 | 0·362 | 0·188 | 0·107 | 2,500 |
| 2,490 | | | | | | | | | | | | 1·[illegible] | 0·515 | 0·267 | 0·150 | 3,000 |
| 2,905 | | | | | | | | | | | | | 0·697 | 0·365 | 0·204 | 3,500 |
| 3,320 | | | | | | | | | | | | | 0·910 | 0·472 | 0·263 | 4,000 |
| 3,735 | | | | | | | | | | | | | | 0·[illegible]93 | 0·333 | 4,500 |
| 4,150 | | | | | | | | | | | | | | 0·730 | 0·408 | 5,000 |
| 4,980 | | | | | | | | | | | | | | | 0·[illegible]85 | 6,000 |

The frictional loss is increased by bends or irregularities in the pipes.

## Comparison between the Scales of Centigrade and Fahrenheit Thermometers.

| Cent. | Fahr. | Cent. | Fahr. | Cent. | Fahr. |
|---|---|---|---|---|---|
| −73 | −100·0 | −24 | −11·2 | +25 | +77·0 |
| −72 | −97·6 | −23 | −9·3 | +26 | +78·8 |
| −71 | −95·8 | −22 | −7·6 | +27 | +80·6 |
| −70 | −94·0 | −21 | −5·8 | +28 | +82·4 |
| −69 | −92·2 | −20 | −4·0 | +29 | +84·2 |
| −68 | −90·4 | −19 | −2·2 | +30 | +86·0 |
| −67 | −88·6 | −18 | −0·4 | +31 | +87·8 |
| −66 | −86·8 | −17 | +1·4 | +32 | +89·6 |
| −65 | −85·0 | −16 | +3·2 | +33 | +91·4 |
| −64 | −83·2 | −15 | +5·0 | +34 | +93·2 |
| −63 | −81·4 | −14 | +6·8 | +35 | +95·0 |
| −62 | −79·6 | −13 | +8·6 | +36 | +96·8 |
| −61 | −77·8 | −12 | +10·4 | +37 | +98·6 |
| −60 | −76·0 | −11 | +12·2 | +38 | +100·4 |
| −59 | −74·2 | −10 | +14·0 | +39 | +102·2 |
| −58 | −72·4 | −9 | +15·8 | +40 | +104·9 |
| −57 | −70·7 | −8 | +17·6 | +41 | +105·8 |
| −56 | −68·8 | −7 | +19·4 | +42 | +107·6 |
| −55 | −67·0 | −6 | +21·2 | +43 | +109·4 |
| −54 | −65·3 | −5 | +23·0 | +44 | +111·2 |
| −53 | −63·4 | −4 | +24·8 | +45 | +113·0 |
| −52 | −61·6 | −3 | +26·6 | +46 | +114·8 |
| −51 | −59·8 | −2 | +28·4 | +47 | +116·6 |
| −50 | −58·0 | −1 | +30·2 | +48 | +118·4 |
| −49 | −56·2 | +0 | +32·0 | +49 | +120·2 |
| −48 | −54·4 | +1 | +33·8 | +50 | +122·0 |
| −47 | −52·6 | +2 | +35·6 | +51 | +123·8 |
| −46 | −50·8 | +3 | +37·4 | +52 | +125·6 |
| −45 | −49·0 | +4 | +39·2 | +53 | +127·4 |
| −44 | −47·2 | +5 | +41·0 | +54 | +129·2 |
| −43 | −45·4 | +6 | +42·8 | +55 | +131·0 |
| −42 | −43·6 | +7 | +44·6 | +56 | +132·8 |
| −41 | −41·8 | +8 | +46·4 | +57 | +134·6 |
| −40 | −40·0 | +9 | +48·2 | +58 | +136·4 |
| −39 | −38·2 | +10 | +50·0 | +59 | +138·2 |
| −38 | −36·4 | +11 | +51·8 | +60 | +140·0 |
| −37 | −34·6 | +12 | +53·6 | +61 | +141·8 |
| −36 | −32·8 | +13 | +55·4 | +62 | +143·6 |
| −35 | −31·0 | +14 | +57·2 | +63 | +145·4 |
| −34 | −29·2 | +15 | +59·0 | +64 | +147·2 |
| −33 | −27·4 | +16 | +60·8 | +65 | +149·0 |
| −32 | −25·6 | +17 | +62·6 | +66 | +150·8 |
| −31 | −23·8 | +18 | +64·4 | +67 | +152·6 |
| −30 | −22·0 | +19 | +66·2 | +68 | +154·4 |
| −29 | −20·2 | +20 | +68·0 | +69 | +156·2 |
| −28 | −18·4 | +21 | +69·8 | +70 | +158·0 |
| −27 | −16·6 | +22 | +71·6 | +71 | +159·8 |
| −26 | −14·8 | +23 | +73·4 | +72 | +161·6 |
| −25 | −13·0 | +24 | +75·2 | +73 | +163·4 |

## To convert Degrees Centigrade or Reaumur into Degrees Fahrenheit, etc.

| | |
|---|---|
| $\frac{\text{Centigrade}^\circ \times 9}{5} + 32 = \text{Fahr.}^\circ$ | $\frac{\text{Fahr.}^\circ - 32 \times 4}{9} = \text{Réaumur}^\circ$ |
| $\frac{\text{Réaumur}^\circ \times 9}{4} + 32 = \text{Fahr.}^\circ$ | $\frac{\text{Centigrade}^\circ \times 4}{5} = \text{Réaumur}^\circ$ |
| $\frac{\text{Fahr.}^\circ - 32 \times 5}{9} = \text{Cent.}^\circ$ | $\frac{\text{Réaumur}^\circ \times 5}{4} = \text{Centigrade}^\circ$ |

## Useful Information.

A gallon of water contains 231 cubic in., and weighs $8\frac{1}{3}$ lbs. (U.S. standard).

A cubic foot of water contains $6\frac{1}{4}$ gallons, and weighs $62\frac{1}{2}$ lbs.

The friction of liquids and vapours through pipes increases as the square of the velocity.

Sensible heat of a liquid is the amount indicated by the thermometer when immersed in it.

Specific heat is the amount of heat absorbed to produce sensible heat.

Latent heat is the amount of heat required for the conversion into vapour after a liquid has reached its boiling-point.

The latent heat of vapour is given off whilst condensing to a liquid; the sensible heat is retained.

One U.S. gallon = 0·133 cubic ft.; 0·83 imperial gallon; 3·8 litres.

An imperial gallon contains 277·274 cubic in.; 0·16 cubic ft.; 10·00 lbs.; 1·2 U.S. gallons; 4·537 litres.

A cubic inch of water = 0·03607 lb.; 0·003607 imperial gallon; 0·004329 U.S. gallon.

A cubic foot of water = 6·25 imperial gallons; 7·48 U.S. gallons; 28·375 litres; 0·0283 cubic metre; 62·35 lbs.; 0·557 cwt.; 0·028 ton.

A lb. of water = 27·72 cubic in.; 0·10 imperial gallon; 0·83 U.S. gallon; 0·4537 kilo.

One cwt. of water = 11·2 imperial gallons; 13·44 U.S. gallons; 1·8 cubic ft.

A ton of water = 35·84 cubic ft.; 224 imperial gallons; 298·8 U.S. gallons; 1,000 litres (about); 1 cubic metre (about).

A litre of water = 0·22 imperial gallon; 0·264 U.S. gallon; 61 cubic in.; 0·0353 cubic ft.

A cubic metre of water = 220 imperial gallons; 264 U.S. gallons; 1·308 cubic yard; 61·028 cubic in.; 35·31 cubic ft.; 1,000 kilos; 1 ton (nearly); 1,000 litres.

A kilo of water = 2·204 lbs.

A vedros of water = 2·7 imperial gallons.

An eimer of water = 2·7 imperial gallons.

A pood of water = 3·6 imperial gallons.

A Russian fathom = 7 ft.

One atmosphere = 1·054 kilos per square in.

One ton of petroleum = 275 imperial gallons (nearly); 360 U.S. gallons (nearly).

A column of water 1 ft. in height = 0·434 lb. pressure per square in.

A column of water 1 metre in height = 1·43 lb. pressure per square in.

One lb. pressure per square in. = 2·31 ft. of water in height.

One U.S. gallon of crude petroleum = 6·5 lbs. (about).

According to Prof. Siebel, about ten B.T.U. of heat will pass through a square foot of ice 1 inch thick in one hour for every degree Fahrenheit difference between the temperatures on either side of the ice sheet.

A cubic foot of ice weighs approximately 57·5 lbs.

A cubic foot of water frozen at 32° makes 1·0855 cubic ft. of ice.

One French horse-power = 75 kilogrammetres (542·533 foot-pounds) per second.

One force de cheval = 0·986337 horse-power.

One horse-power = 1·01385 force de cheval.

Indicated French horse-power = 3·49 $D^2PRS$.

D = dia. of cy. in metres, S = length of stroke in metres, R = number of revs. per minute, and P = average pressure on piston in kilogs. per square centimetre.

## Fractions of an Inch and Decimal Equivalents.

| Fractions. | Inch. | Fractions. | Inch. | Fractions. | Inch |
|---|---|---|---|---|---|
| 1-32 | 0·03125 | 3-8 | 0·375 | 23-32 | 0·71875 |
| 1-16 | 0·0625 | 13-32 | 0·40625 | 3-4 | 0·75 |
| 3-32 | 0·09375 | 7-16 | 0·4375 | 25-32 | 0·78125 |
| 1-8 | 0·125 | 15-32 | 0·46875 | 13-16 | 0·8125 |
| 5-32 | 0·15625 | 1-2 | 0·5 | 27-32 | 0·84375 |
| 3-16 | 0·1875 | 17-32 | 0·53125 | 7-8 | 0·875 |
| 7-32 | 0·21875 | 9-16 | 0·5625 | 29-32 | 0·90625 |
| 1-4 | 0·25 | 19-32 | 0·59375 | 15-16 | 0·9375 |
| 9-32 | 0·28125 | 5-8 | 0·625 | 31-32 | 0·96875 |
| 5-16 | 0·3125 | 21-32 | 0·65625 | | |
| 11-32 | 0·34375 | 11-16 | 0·6875 | | |

## Comparison of British Measures with U.S.

| United States Standard. | | | British Standard. | |
|---|---|---|---|---|
| | 1 gill | = 0·833565 | imperial | gill. |
| 4 gills = | 1 pint | = 0·833565 | ,, | pint. |
| 2 pints = | 1 quart | = 0·833565 | ,, | quart. |
| 4 quarts = | 1 gallon | = 0·833565 | ,, | gallon. |

An imperial gallon = 4·5435 litres = 1·19968 U.S. standard gallons.

An imperial gallon contains (Act of Parliament, 1878) 10 lbs. of water at a temperature of 62° Fahr. Its accepted volume is 277·274 cubic in.

## Specific Gravities of Gases.

| Gas at 32° and below one atmosphere. | Specific gravity. | Cubic feet in 1 lb. |
|---|---|---|
| Air .. .. | 1·000 | 12·38 |
| Ammonia .. | 0·589 | 21·01 |
| Carbonic acid .. | 1·529 | 8·10 |
| Chlorine .. | 2·440 | 5·07 |
| Nitrogen .. | 0·978 | 12·72 |
| Oxygen .. | 1·105 | 11·20 |

## Information required by Manufacturers to enable them to estimate for the Cost of a Refrigerating Plant.

1. The length, breadth, and height of the cellars, rooms, or stores to be refrigerated. If the ceiling or roof is vaulted, the height to the centre and spring of the arch will be required. Full particulars of the means of insulation adopted, or, if none exist, of the materials from which the chambers are built.

2. Whether it is desired to refrigerate on the direct expansion, on the brine circulation, or on the cold-air system.

3. The temperature desired to be maintained in each chamber or store.

4. The nature of the substance which it is desired to refrigerate.

5. In the case of a packing-house, or an abattoir, the largest number of carcases to be cooled daily, and their average weight.

6. In the case of a freezing chamber for beef, mutton, or other produce, the number of carcases, etc., to be frozen in each 24 hours, and their average weight.

7. When a liquid is to be cooled, the number of gallons, or barrels, to be dealt with per hour, and from what temperature down.

8. The nature, quantity, and temperature of the water supply available for use.

9. Rough dimensioned plan of the establishment, showing the most convenient spot to locate the refrigerating machine.

## Information required by Manufacturers to enable them to estimate for the Cost of an Ice-making Plant.

1. Number of tons of ice that it is desired to produce per 24 hours.

2. If clear, crystal, transparent ice is required, or whether opaque ice will do for the purpose.

3. The nature, quantity, and temperature of the supply of water procurable for use.

4. Whether there is an available source of steam supply on the premises; and if spare steam-power, then how many horse-powers could be utilised.

5. When the installation is to be erected in existing buildings, a rough dimensioned plan of same.

6. Where an estimate of cost of making ice is required, price and quality of fuel; wages of engine-drivers, stokers, and common labourers, for 12 hours day work, and for 12 hours night work; if water has to be bought, cost of same.

## Various Horse-powers in Use.

| | Kilogrammetres per second. | Foot-pounds per minute. | Ratio to British H.P. |
|---|---|---|---|
| Austria .. .. | 76·419 | 33,034 | 1·001 |
| Baden .. .. | 75·000 | 32,552 | 0·986 |
| France .. .. | 75·000 | 32,552 | 0·986 |
| Great Britain .. | 76·041 | 33,000 | 1·000 |
| Hanover .. .. | 75·361 | 32,705 | 0·990 |
| Prussia .. .. | 75·325 | 32,689 | 0·990 |
| Saxony .. .. | 75·045 | 32,568 | 0·986 |
| Wurtemburg .. | 75·240 | 32,637 | 0·988 |

## Expansion in Steam Pipes.

The expansion and contraction of steam pipes is about 1 inch in 50 feet by reason of temperature variations. This expansion and contraction may be provided for in the case of long lengths of pipe between fixed abutments, by spring bends or lengths, or by expansion sockets. In the latter case, guard bolts should be fitted to prevent the pipes from being drawn out of the sockets.

## Rough Rules to Ascertain Amounts of NaCl and CaCl required for Ice-tank of Given Capacity. —*Matthews*, "Power."

Allow 15 pounds of salt per cubic foot of brine actually required to fill the tank when the cans are in place, or allow two-thirds ton of salt per ton of ice-making capacity of tank per 24 hours. For $CaCl_2$ some authorities estimate the amount required at one ton, per ton of ice-making capacity.

## GENERAL INFORMATION REGARDING CYLINDERS OF $CO_2$.
(*Birmingham Carbonic Acid Works.*)

Each cylinder contains 28 lbs. avoirdupois of pure liquefied $CO_2$ (In accordance with the Government Committee's recommendations, the cylinder capacity is such that this weight of $CO_2$ equals 75 per cent. of its water capacity.)

Each pound of liquid $CO_2$ represents about $\frac{1}{9}$ gallon of gas in its compressed state, which at mean temperature will expand to about 450 times its volume, or, to 1400 gallons of $CO_2$.

Each cylinder is fitted with a valve which is protected by a removable iron cap, and the top of each protecting cap forms a key to open the valve. A turn to the left opens the cylinder valve and liberates the gas. To shut off, turn to the right.

Full cylinders should be kept in a cool place, to prevent unnecessary expansion of the $CO_2$, and under cover to obviate oxidation and consequent deterioration.

Cylinders require annealing and testing at intervals.

## TO TEST THE PURITY OF LIQUID $CO_2$.

The purity of liquefied carbonic acid can be tested by solidifying it, in which state the slightest impurity can be immediately detected by smelling. The solidification can be effected by placing the tube in a horizontal position on some suitable support, and fastening a small linen or canvas bag 4 to 6 inches square over the nozzle and opening the valve fully. The liquid acid will then stream out with full force, become solid inside the bag, and remain in that state for hours, only evaporating slowly, and showing a temperature of 200° Fahr. below freezing-point.

## REGENERATION OF COLD AIR.

It is said that cold air may with advantage be regenerated by being ozonized before use in a cold store where the closed circuit system is in use. Air becomes more or less charged with disagreeable and noxious emanations after passing over

certain products—notably many kinds of fruit; these emanations are destroyed by the action of the ozone, whilst at the same time the air is sterilized, and the formation of spores of mould peculiar to cold rooms is obviated.

VALUE OF THE CO-EFFICIENCY OF PERFORMANCE OF HEAT-ENGINE, UPPER LIMIT OF TEMPERATURE VARYING BETWEEN 32° AND 100° F. AND THE LOWER LIMIT OF TEMPERATURE LYING BETWEEN −80° AND 30° F. (*Prof. G. J. Wells, "Proceedings, Inst. of Mech. Engrs.*, 1914.")

| Lower limit of temperature in degrs. Fahr | Upper Limit of Temperature Deg. Fahr | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 32 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 30 | 245 | 49 | 24·5 | 16·3 | 12·2 | 9·8 | 8·2 | 7·0 |
| 20 | 40 | 24 | 16·0 | 12·0 | 9·6 | 8·0 | 6·8 | 6·0 |
| 10 | 21·3 | 15·6 | 11·7 | 9·4 | 7·8 | 6·7 | 5·9 | 5·2 |
| 0 | 14·4 | 11·5 | 9·2 | 7·7 | 6·6 | 5·8 | 5·1 | 4·6 |
| 10 | 10·6 | 9·0 | 7·5 | 6·4 | 5·6 | 5·0 | 4·5 | 4·1 |
| 20 | 8·45 | 7·3 | 6·3 | 5·5 | 4·9 | 4·4 | 4·0 | 3·7 |
| 30 | 6·9 | 6·1 | 5·4 | 4·8 | 4·3 | 3·9 | 3·6 | 3·3 |
| 40 | 5·8 | 5·2 | 4·7 | 4·2 | 3·8 | 3·5 | 3·2 | 3·0 |
| 50 | 5·0 | 4·5 | 4·1 | 3·7 | 3·4 | 3·1 | 2·9 | 2·7 |
| 60 | 4·3 | 4·0 | 3·6 | 3·3 | 3·1 | 2·9 | 2·7 | 2·5 |
| 70 | 3·8 | 3·5 | 3·2 | 3·0 | 2·8 | 2·6 | 2·4 | 2·3 |
| 80 | 3·4 | 3·2 | 2·9 | 2·7 | 2·5 | 2·4 | 2·2 | 2·1 |

APPARATUS FOR PRESERVING FISH FOR TRANSPORT.

The apparatus—which is a Danish invention—comprises a wooden tank, having an internal cylindrical metal part with openings at both top and bottom, and fitted with a revolving shaft, at the base of which is mounted a propeller. This metal vessel is charged with a mixture of ice and salt, and the outer tank is filled with sea-water. The revolving propeller forces the brine through the apertures in the metal container into the wooden tank, creating a continuous circulation of the saline solution, and rapidly coating the fish placed in the brine with a layer of ice.

## DIMENSIONS OF AMMONIA COMPRESSION MACHINES.

(*J. Wemyss Anderson, M.Eng., "Proceedings, Inst. Mech. Engrs.,* 1912.")

| Number of Machines. | Per day of 24 hours | | | I.H.P. of Engine | Compressor (Dimensions in Inches). | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ice Making. | Ice Melting | Effective B.Th.U. removed | | R.P.M. | Diameter and Stroke. | Suction Valves Diameter. | Delivery Valves Diameter. | Diameter of Pipes. | Rod. |
| | Tons. | Tons. | | | | | | | | |
| 1 | 5 | 11·7 | $3·5 \times 10^6$ | 17 | 70 to 80 | $7\frac{1}{4} \times 15$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | 2 | $1\frac{7}{8}$ |
| 2 | 10 | 20·0 | $6 \times 10^6$ | 27 | 65 to 75 | $9 \times 18$ | $3\frac{1}{8}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ |
| 3 | 25 | 45·0 | $13·5 \times 10^6$ | 60 | 60 to 70 | $12 \times 24$ | $4\frac{1}{4}$ | $3\frac{3}{4}$ | 3 | 3 |
| 4 | 50 | 87·0 | $26 \times 10^6$ | 110 | 55 to 65 | $15·5 \times 30$ | $5\frac{1}{2}$ | 5 | 4 | $3\frac{7}{8}$ |
| 5 | 100 | 170·0 | $51 \times 10^6$ | 210 | 50 to 60 | $21 \times 36$ | $7\frac{1}{2}$ | 7 | 5 or 6 | $5\frac{1}{4}$ |

NOTE.—(*a*) Number of machine for reference in Table on page 203 only.

(*b*) The higher figures in revolutions to meet overloads.

## Ammonia Compression Machines. Heat Units and Condensing Water. Condensing Water on at 55° F. and off 80° F.

(*J. Wemyss Anderson, M.Eng.*, "*Proceedings, Inst. Mech. Engrs.*, 1912.")

| Number of Machine. | B.Th.U. per 24 hours. | | | | Condensing Water. Gallons per hour. Submerged | |
|---|---|---|---|---|---|---|
| | Removed from cold body or effective | Allowance for leakage into Machine and Connections, etc. | Heat Equivalent of Work Expanded | Total Removed. | Total | Per ton Ice Making. |
| 1 | 3,500,000 | 265,000 | 1,041,000 | 4,806,000 | 800 | 160 |
| 2 | 6,000,000 | 440,000 | 1,660,000 | 8,100,000 | 1,350 | 135 |
| 3 | 13,500,000 | 990,000 | 3,700,000 | 18,190,000 | 3,030 | 121 |
| 4 | 26,000,000 | 2,000,000 | 6,800,000 | 34,800,000 | 5,800 | 116 |
| 5 | 51,000,000 | 3,740,000 | 12,890,000 | 67,630,000 | 11,300 | 113 |

# INDEX.

THE END.

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